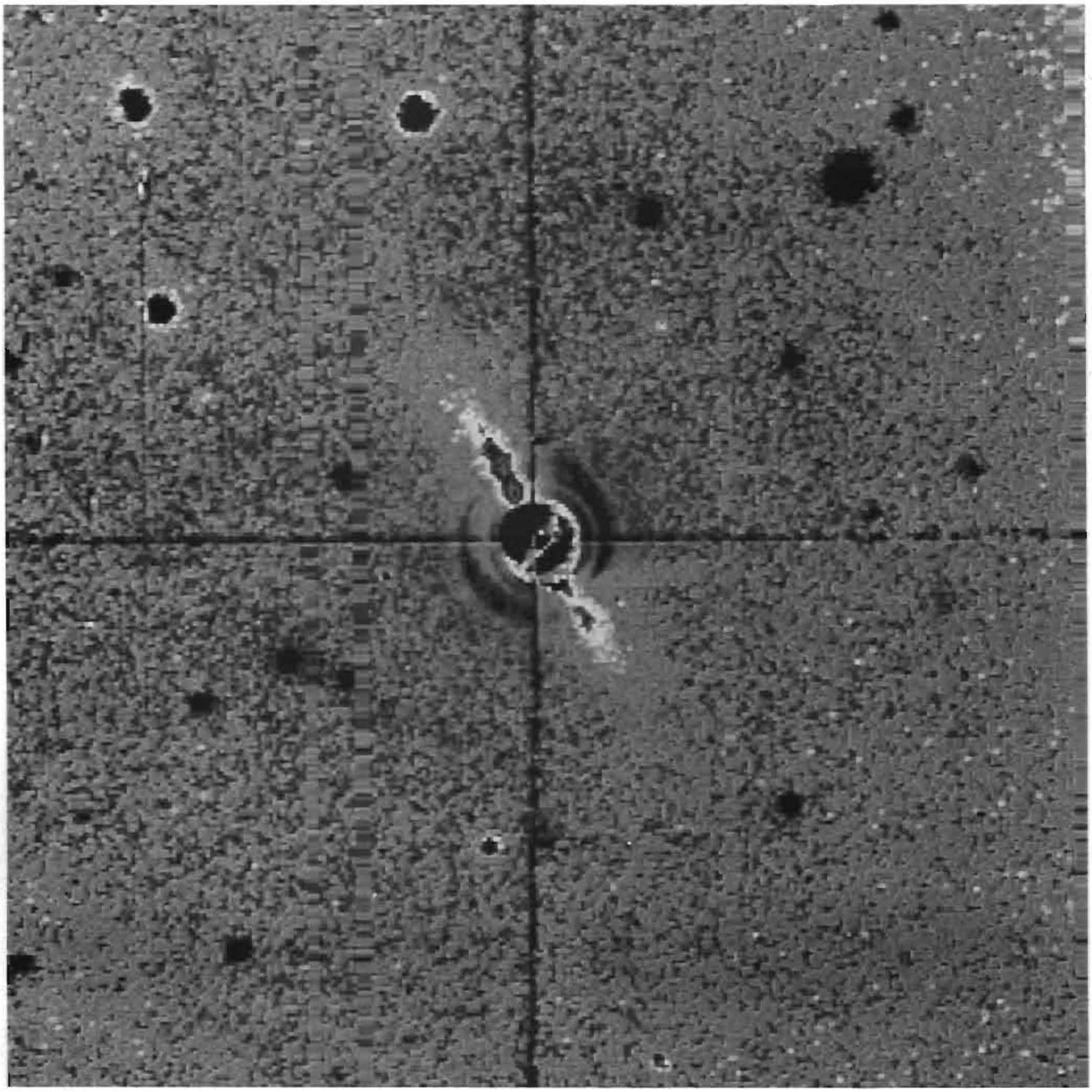
JET PROPULSION LABORATORY
1984 Annual Report



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A description of work accomplished under a contract between the California Institute of Technology and the National Aeronautics and Space Administration for the period January 1 to December 31, 1984.

JET PROPULSION LABORATORY
California Institute of Technology

(Cover) This charge-coupled-device picture of the star Beta Pictoris shows what may be another solar system. The disk of material surrounding Beta Pictoris extends 60 billion kilometers from the star, which is located behind a circular occulting mask in the center of the picture. This material is probably composed of ices, carbonaceous organic substances, and silicates. These are the materials from which the comets, asteroids, and planets of our own solar system are thought to have formed.

DIRECTOR'S MESSAGE

July 1, 1984, marked the 40th anniversary of the formal establishment of the Jet Propulsion Laboratory. Throughout four decades, JPL has maintained a tradition of excellence, from rocket propulsion in the 1940s, to guided-missile systems in the 1950s, and on to spaceflight projects starting in the 1960s. The accomplishments of the past year continued this tradition while opening new possibilities for exploration of Earth and deep space.

A year after completing its mission, the Infrared Astronomical Satellite (IRAS) continued to reveal new discoveries as data processing progressed and the first catalogs were released. One class of IRAS findings—the discovery of extended infrared emission from numerous nearby stars—led to the dramatic JPL/University of Arizona telescopic observations of a disk of material around the star Beta Pictoris. This star, 53 light-years away, may already have around it a system of planets in the early stages of formation—that is, the first such system other than our own ever seen in astronomical photographs.

In spaceflight activities, JPL teams continued preparing for the May 1986 launches of the Galileo Jupiter spacecraft and the U.S.–European Ulysses solar mission. The Core Program of missions recommended by NASA's Solar System Exploration Committee moved forward, as work progressed on the Venus Radar Mapper and JPL received approval to begin the Mars Observer. The next proposed core mission, the Comet Rendezvous Asteroid Flyby, is in the detailed planning stage, aimed at a fiscal 1987 new start.

Voyager 2 continued its trek through the outer solar system on its way to close approaches of Uranus in January 1986 and Neptune in August 1989. The spacecraft's twin, Voyager 1, moved farther from the plane of the ecliptic, eventually to leave our solar system. The JPL-managed Deep Space Network of antennas underwent further modifications and improvements in preparation for the Voyager 2 encounters and the greater communications challenges that lie ahead.

Increased appreciation of Earth as a planet where land, sea, and air interact as a system motivates our global observation program. As part of a NASA and international effort, JPL is developing spacecraft and instruments for free-flying missions as well as experiments to be flown on the space shuttles. One of these, the Shuttle Imaging Radar (SIR-B), flew in 1984 and returned valuable data about numerous Earth sites. Several shuttle experiments are scheduled for flight in the coming year. These include the Drop Dynamics Module, whose JPL principal investigator will accompany it into space as a shuttle crew member. The Laboratory will have the opportunity to contribute substantially in this area by applying its unique combination of skills in spacecraft development, systems management, and remote sensing.

JPL's efforts in energy research reached a new milestone in 1984, by bringing two major solar-energy projects to fruition. One was to decrease 100-fold the cost of photovoltaic cells used to power spacecraft, thus permitting their economic application to the generation of electricity on Earth. The second was to develop modules that use large point-focusing mirrors to concentrate the sun's rays and produce electric power. Industrial sources for both types of solar-electric generating systems have arisen as a result of the technology developed at JPL, and their prospects for commercial exploitation are excellent. The success of these projects was gratifying since it fulfilled their basic objective: to establish a technology base upon which industry can build.

In our pursuit of new technology, we anticipate more complex flight missions that will require advances in autonomy, communications, and spacecraft power. Initiatives such as the Advanced Microelectronics Program (AMP) will serve to maintain and strengthen our technological capabilities. In addition, the accomplishments of individual researchers continue to be noteworthy. To date, 36 peer-reviewed researchers have been appointed as senior research scientists and engineers in recognition of leadership in their fields.

Looking ahead, we foresee dramatic events—the Voyager encounter in January 1986, the dual launches the following May—and many exciting spaceflight opportunities. We can look to the future with optimism, thanks to the renewed strength of the planetary program and the diversity of challenges that await us. We are confident of meeting those challenges with the skills and talents of the outstanding people of JPL, along with the vision that has characterized the Laboratory during its first 40 years.

Lew Allen
Director

INTRODUCTION

The Jet Propulsion Laboratory is operated by the California Institute of Technology for the National Aeronautics and Space Administration. The people of JPL share a common objective: to perform research and development in the national interest.

JPL has three institutional characteristics that shape its philosophy, mission, and goals:

- *As part of Caltech, JPL aims for the highest standards of scientific and engineering achievement; excellence, objectivity, and integrity are its guiding principles.*
- *As part of NASA, JPL has been at the forefront of U.S. lunar and planetary exploration efforts since the establishment of the agency a quarter of a century ago. JPL is NASA's lead center for the exploration of the solar system. In addition to solar system exploration, the Laboratory performs a variety of other research, development, and spaceflight activities for NASA and for other agencies.*
- *As a national research and development center funded by federal dollars, JPL does not compete with private industry, nor does it perform work that should be done in the private sector.*

JPL was formally established on July 1, 1944, as an outgrowth of pioneering rocketry work conducted in the 1930s and '40s under the leadership of Caltech Professor Theodore von Kármán. From these modest beginnings, JPL has grown into a pre-eminent national laboratory with a budget of more than $600 million and a work force of some 5,000.

The primary mission of the Laboratory evolved, as the rocketry research of the 1940s gave way to guided-missile work in the 1950s and then, in the late '50s and early '60s, to spaceflight projects for NASA.

JPL built the first U.S. satellite, Explorer 1, and the first planetary spacecraft, Mariner 2, which flew by Venus in 1962. Since then, the Laboratory has sent more than 20 unmanned scientific spacecraft on missions to the moon, Mercury, Venus, Mars, Jupiter, and Saturn. These missions—the Rangers, Surveyors, Mariners, Vikings, and Voyagers—have vastly increased our understanding of the solar system. The coming Voyager 2 encounters of Uranus and Neptune will complete the initial reconnaissance of the solar system.

In the 1980s and 1990s, the Core Program of missions advocated by NASA's Solar System Exploration Committee will be implemented. This program emphasizes simpler spacecraft, to conserve budget resources, but the missions will be demanding and will provide dramatic and important scientific discoveries. JPL, which will manage these core missions, is

also participating in the planning of more complex "augmentation" missions—such as a Mars Sample Return—that would be flown in the more distant future.

The year 1984 was one of accomplishment and progress:

- *In the area of Deep-Space Exploration, processing of data from the Infrared Astronomical Satellite revealed several new discoveries. Development progressed on a number of flight missions, including Galileo to Jupiter, the Ulysses international probe to the sun, and the first core missions, the Venus Radar Mapper and the Mars Observer.*
- *Upgrading continued in Telecommunications Systems, as the Deep Space Network, through which controllers communicate with distant U.S. spacecraft, was expanded. JPL is preparing for the greater communications challenges that lie ahead both in deep space and in Earth orbit.*
- *Investigators in Earth Observations continued their studies of our planet, with a new emphasis on Earth as a system of interacting parts. JPL is developing instruments and spacecraft that will help provide an improved global viewpoint of the changing Earth.*
- *Work continued on several JPL initiatives in Advanced Technology, including microelectronics and concurrent processing, optical systems, and space telerobotics.*
- *The growth in JPL's Defense Programs continued in 1984, with several challenging analysis and hardware-development projects. These projects give JPL an opportunity to apply and strengthen its technological capabilities while enhancing national security.*
- *Researchers in the Civil Program announced numerous advances in energy and technology applications in 1984. This research ranged widely over the fields of alternative energy, energy conservation, environmental technology, biomedical technology, and aviation.*

The remainder of this report discusses the many highlights of the past year.

The annals of science contain numerous examples of independent research breakthroughs that converged suddenly and in such a way that our perspective was forever altered. The year 1984 brought just such an occurrence, as two breakthroughs enabled us to move beyond mere speculation about other planetary systems to the first direct evidence of systems of matter orbiting other stars.

During the year, the continuing analysis of data from the JPL-managed Infrared Astronomical Satellite (IRAS) provided the first breakthrough by revealing that many nearby stars are surrounded by cool material interpreted as extended regions of dust—perhaps, IRAS scientists theorized, protoplanetary systems in various stages of formation.

The second breakthrough came when astronomers from JPL and the University of Arizona, working independently of IRAS and employing special optical and computer techniques, conducted telescopic observations of one of these stars—Beta Pictoris, 53 light-years from Earth. Their observations clearly revealed a disk of particles around the star.

Does this material constitute planets? Are systems like that at Beta Pictoris rare, or fairly common, throughout the cosmos? The past year's findings raise a number of such questions that cannot yet be answered. Whatever the answers, these findings increase our expectations of discovering extrasolar planetary systems.

By year's end, IRAS data processing had revealed some 40 stars within 100 light-years of Earth characterized by the type of infrared-energy excess found at Beta Pictoris. Thus, there are many potential targets for new space- and ground-based instruments being planned for future deployment; these instruments include the Hubble Space Telescope and its JPL/Caltech camera system.

JPL activity increased in 1984 in anticipation of the January 1986 encounter of Voyager 2 with the planet Uranus. JPL teams also continued preparations for the May 1986 launches of Galileo to Jupiter and of Ulysses to observe the polar regions of the Sun.

Work proceeded on two of JPL's newest flight projects, the Venus Radar Mapper and the Mars Observer, which are the first elements of the Core Program of low-cost missions advocated by the NASA Solar System Exploration Committee. Later core missions are to be developed by JPL as either Planetary Observers to the inner solar system or Mariner Mark II flights to more distant targets. The Planetary Observer line, of which the Mars Observer is the first, will consist of commercial Earth orbiters modified for use in deep space. Mariner Mark II will be a new class of spacecraft that can be easily reconfigured for a variety of missions.

These and other proposed efforts will continue our exploration of the solar system and will perhaps lay the foundation for the ultimate exploration of systems at other stars.

Flight Projects

INFRARED ASTRONOMICAL SATELLITE

The Infrared Astronomical Satellite (IRAS) completed its data-acquisition phase in November 1983 after having surveyed nearly the entire sky in its search for objects emitting infrared energy.

The year 1984 was mainly devoted to processing more than 20 billion bits of IRAS data for the use of astronomers around the world for decades to come. The principal product of this effort was the Point Source Catalog, which, along with other data products, was released in November.

This listing contains a staggering 245,839 point sources, of which about half are stars and another quarter are galaxies. The catalog gives their location in the sky, their brightness as observed in each of the four IRAS infrared-wavelength bands, and miscellaneous other information. By comparison, only 5,000 sources were listed in the Caltech Two-Micron Sky Survey of the 1960s, and the latest NASA Catalog of Infrared Observations contains only about 10,000 sources. The IRAS catalog also gives more information about each source than do any of its predecessors.

In addition, project scientists issued the first of three sets of maps showing diffuse infrared emission from the more than 95 percent of the sky that IRAS surveyed. Each map covers a 16-degree square, and 212 maps are required to cover the surveyed sky. Other data products were being prepared as well, among them a catalog of small extended sources and several subsets of the primary catalog, separately listing variable sources (about 12,000 in number), stars, galaxies, and sources outside the galactic plane.

Because of IRAS's success, NASA decided to continue its funding for at least five years and to authorize the project to establish an Infrared Processing and Analysis Facility. The facility, to be housed in a new building on the Caltech campus, will accommodate continuing processing of the IRAS data set and further research by astronomers.

The IRAS science team announced several interesting findings during the year. As examples,

- The infrared galaxy Arp 220 (also known as IC 4553) emits 80 times more energy in the infrared than in the visible and is as bright as about 2 million million suns.
- About 10 percent of nearby main-sequence dwarf stars exhibit an infrared excess suggestive of a cool ring or shell of material—perhaps the beginnings of planetary formation—similar to that first discovered around Vega in 1983.
- Interacting and merging galaxies as a class have much larger infrared luminosities than non-interacting spiral galaxies; the

emission probably comes from massive star formation and constitutes a substantial fraction of the total extragalactic infrared flux.

JPL serves as U.S. project manager for the joint American–Dutch–British IRAS effort.

VOYAGER

Voyagers 1 and 2 have already completed their primary missions, which were the planetary encounters with Jupiter and Saturn; the last Saturn encounter took place in August 1981. Voyager 2 is now drawing near largely unknown Uranus and will fly by that planet on January 24, 1986. The more distant Voyager 1 has no further planetary encounters on its agenda, but is conducting measurements of the interplanetary medium and acting as a specialized astronomical observatory.

The past year saw a gradual increase in scientific activity in preparation for the Uranus encounter. Project scientists met early in 1984 to establish their goals. During the summer, planning began for the observational sequences during the crucial period of November 1985 through March 1986. This process will continue in greater detail throughout 1985, culminating in a set of instructions for the Voyager computers to guide the spacecraft on its tour through the Uranian system.

By the end of 1984, the occasional Voyager 2 images of Uranus were comparable to the best obtainable from the ground; the new images revealed some indications of atmospheric activity on the planet.

Uranus' great distance from Earth and the age of Voyager 2 have necessitated a number of changes in plans for mission operations. These changes include the development of new methods for using the balky gear system that moves Voyager 2's cameras, and a clever way of compressing data on board the spacecraft before transmission to Earth. In addition, dramatic improvements have been achieved in the capability of the Deep Space Network antennas to collect Voyager data—for example, a major upgrading of equipment, and arrangements for arraying NASA's antennas with those of other U.S. and foreign agencies.

After Uranus Voyager 2 will proceed to Neptune, currently the most distant planet from the sun, for an encounter in August 1989. (While Pluto is normally our most distant planet, its eccentric orbit has taken it, at present, inside the orbit of Neptune; this alignment will continue until 1999.)

Both JPL-managed Voyagers continue on paths of escape from the solar system; they could encounter our system's electromagnetic boundary, the heliopause, sometime in the next decade. In fact, their instruments are already picking up faint radio signals that may be coming from this final edge of the solar system, beyond which lies interstellar space.

GALILEO

The ambitious Galileo flight to Jupiter will begin in May 1986, when the spacecraft is deployed from the shuttle Atlantis and is accelerated from Earth orbit by a Centaur upper-stage rocket onto a Jupiter trajectory.

There are two Galileo craft: an orbiter and an atmospheric probe. The dual-spin orbiter will carry the probe piggyback fashion from Earth to the vicinity of Jupiter and then deploy the small craft on a brief but scientifically valuable plunge into the planet's atmosphere. The orbiter will go on to conduct a detailed reconnaissance of the Jovian system, highlighted by close flybys of all the major satellites. The scheduled arrival date is December 10, 1988; the orbiter's nominal mission will last 22 months.

Component redesign and replacement continued in 1984 in the wake of findings from the earlier Voyager and Pioneer missions to Jupiter. Analysis of data from these flights revealed that there are significantly more very-high-energy oxygen and sulfur ions trapped in the inner parts of Jupiter's magnetic field than was once thought. Although these particles do not present a radiation-damage hazard, they could change values in the onboard computer memory registers. This phenomenon—known as "single-event upset," or SEU—has been shown to affect many of the parts used in today's spacecraft.

All redesign work in response to the SEU studies had been completed and some parts in sensitive subsystems had been replaced by year's end; the balance of retrofitting will not affect project schedules.

The pace of spacecraft buildup quickened throughout 1984 as the launch drew closer. A yearlong phase of integrating and testing the orbiter/probe began with delivery of the spacecraft bus, the flight instruments, the engineering subsystems, the probe, and the retropropulsion module.

The assembly and integration phase began in January, as the spacecraft engineering subsystems were reassembled with the flight structure and the science instruments. System testing began in April as Galileo operated in a simulation of the mission profile.

Galileo was then configured to the launch mode for the first phase of environmental tests. For nearly four months, the spacecraft underwent vibration, acoustic, pyrotechnic shock, and radio-frequency interference (RFI) tests—all to prove its readiness for the launch environment. A cruise and encounter test was conducted to ensure that Galileo will withstand the RFI environment anticipated at Jupiter.

A second phase of system tests followed in the fall, to determine how well the spacecraft survived this earlier testing. At year's end, Galileo was undergoing a second series of environmental tests, to verify the thermal design of the spacecraft.

JPL, the overall Galileo project manager for NASA, designed and built the orbiter and will direct the flight. The probe was developed by NASA's Ames Research Center and built by Hughes Aircraft Company. The retropropulsion module was furnished by Bundesministerium für Forschung und Technologie as a joint international venture with West Germany.

ULYSSES

At midyear, the joint U.S./European International Solar Polar Mission (ISPM) was renamed "Ulysses." Development has continued toward the planned May 1986 launch.

The name was selected by the European Space Agency (ESA), with NASA concurrence, in reference not only to Homer's mythological hero, but also to the Italian poet Dante's description (in the 26th Canto of his Inferno*) of Ulysses' urge to explore "an uninhabited world behind the sun."*

This citation from Dante is appropriate, for our modern Ulysses will permit the first-ever measurements away from the ecliptic plane and over the poles of the sun, into the uncharted third dimension of the heliosphere. The spacecraft will investigate the properties of the solar wind, the structure of the sun/wind interface, the heliospheric magnetic field, the interplanetary magnetic field, the solar wind plasma, solar and galactic cosmic rays, and cosmic dust.

Ulysses will be launched in May 1986 toward a unique elliptical transfer orbit around Jupiter; this launch, like that of Galileo, will be by a shuttle/Centaur combination. (Ulysses will precede Galileo into space by about a week.) After a 14-month journey to Jupiter, the Ulysses spacecraft will be deflected by the giant planet's gravity into a highly inclined orbit out of the ecliptic and back over the sun. Ulysses' investigation of first one pole of the sun, and later the other, will begin in late 1989 or early 1990.

The completed spacecraft, built by Dornier Systems of West Germany, remained in storage throughout 1984 while the nine science instruments, six sponsored by the United States, underwent refurbishment. Before year's end, the instruments' refurbishment and reacceptance reviews were completed in preparation for return to Europe in early 1985. The spacecraft itself will come out of storage and the instruments will be reintegrated in early spring.

Ulysses mission operations will be conducted at JPL, which serves as the NASA project manager. Plans now being implemented call for an ESA team to operate the spacecraft from JPL for the duration of the mission; the Laboratory will provide operations support to the ESA team, as well as navigation, tracking support, and data records.

WIDE-FIELD/PLANETARY CAMERA

Much of 1984 was required for the integration and installation of the Wide-Field/Planetary Camera (WFPC) into the Hubble Space Telescope, an Earth-orbiting spacecraft scheduled for launch in late 1986. This work took place at the Lockheed Missiles and Space Company, the prime contractor for the Space Telescope.

The WFPC was shipped to Lockheed in July after completion of the science instrument integration tests at NASA's Goddard Space Flight Center and minor modification and recalibration at JPL. Some consideration was given at year's end to yet another calibration at JPL.

There are two complete camera systems within the WFPC: one can record extraordinarily detailed images of individual objects; the other can provide images of a much wider field of view. Viewing through the 2.4-meter Space Telescope, the cameras will be able to detect objects 100 times fainter than those visible from Earth-based telescopes, with about 10 times greater resolution. Between them, the cameras will image targets that range from asteroids, comets, and planets in our solar system to galaxies and quasars at the edge of the universe.

JPL, which designed and built the instrument with investigators from Caltech, will continue to support the WFPC through launch and subsequent orbital verification.

VENUS RADAR MAPPER

Progress on the Venus Radar Mapper (VRM) mission continued in 1984, with the detailed definition of the mission design and the spacecraft and radar designs. Many of the spacecraft subsystem contracts were let by Martin Marietta Corporation, the spacecraft system contractor, and some of the residual hardware that will be used in the construction of the spacecraft was delivered by JPL.

VRM will be launched by a shuttle/Centaur combination in April 1988 and will arrive at Venus four months later. From an elliptical near-polar orbit, the spacecraft will map nearly the entire planet over the course of one full Venusian rotation (243 Earth days).

The spacecraft will obtain data necessary to understand the geological processes occurring at the surface of Venus, the geological history of the planet, and the processes that are active within its interior. VRM's primary scientific tool, imaging radar, will peer through the opaque clouds of the atmosphere to produce photographic-quality images of the surface. A radar altimeter will measure the topography of the planet to help scientists understand the features seen in the radar images.

Venus holds many important clues necessary for our understanding of Earth. The two planets are similar in their basic characteristics, such as size, mass, mean density, and distance from the sun. Yet they are vastly different in some of their specific characteristics, such as atmospheric composition, temperature, pressure, rotation rate, and large-scale geological features.

The Veneras 15 and 16, launched by the Soviets in 1983, mapped these large-scale features of the northern hemisphere of Venus at a resolution of 1 to 2 kilometers. The Soviet maps demonstrate the potential value of global coverage at significantly higher resolution.

VRM will map more than 70 percent of Venus at a radar resolution of about 150 meters, while resolution over the polar regions will be about 300 meters. In addition, VRM observations will generally be made at high incidence angles suited to imaging rough terrain.

EXTREME ULTRAVIOLET EXPLORER

The Extreme Ultraviolet Explorer (EUVE) was approved by NASA as a new-start project in June 1984.

In late 1988, EUVE will be carried by a space shuttle to an operating altitude of 550 kilometers above Earth's surface. From this vantage point above the atmosphere, the satellite will scan the sky for emissions in the extreme-ultraviolet (EUV) wavelengths.

The primary scientific goal of the mission is to conduct the first all-sky survey for cosmic sources that are far hotter than the surface of the sun or other visible stars. These sources emit radiation in the EUV band (100 to 1,000 angstroms), a red region of the electromagnetic spectrum so far unexplored. Astronomers expect EUVE to discover new celestial objects as well as provide more information about known stars.

EUVE will carry out the all-sky survey portion of the mission using three grazing-incidence telescopes. A fourth instrument, a deep-survey/spectrometer telescope, will conduct a more sensitive study of a portion of the sky, as well as spectroscopic observations of interesting objects identified during the all-sky survey.

JPL will provide overall project management. The Space Sciences Laboratory of the University of California, Berkeley, will furnish the science payload, analyze the scientific data, and run the science operations center.

MARS OBSERVER

The Mars Observer gained approval as a fiscal 1985 new-start project for JPL. The project, formerly known as the Mars Geoscience/Climatology Observer, is the first of the Planetary Observers, a planned series of low-cost missions to the inner planets.

To achieve the goal of low cost, the Planetary Observers will address only the most basic scientific questions and therefore will perform investigations of somewhat limited scope. The missions will also draw on existing designs and technology for the spacecraft and scientific instruments.

The Mars Observer will be launched in August 1990 from a space shuttle and placed on a Mars trajectory by an upper stage. After a one-year transit to the planet, the spacecraft will enter a low polar orbit and begin repeated observations of the atmosphere and surface for one Martian year (687 Earth days).

Mission design during 1984 emphasized orbital performance analysis for compliance with the planetary protection guidelines. In this regard, the spacecraft—at the end of its low-altitude mapping phase at Mars—will be maneuvered into a higher orbit that satisfies long-term planetary quarantine requirements.

During the past year, the procurement approach for the flight system (spacecraft plus upper stage) was defined and the request for proposal (RFP) prepared. The plan is to procure a spacecraft based on a slightly modified Earth orbiter.

Both the flight system RFP and the announcement of opportunity for the scientific payload will be released in 1985, with selection of the spacecraft contractor scheduled for late in the year. The scientific payload will be selected in 1986.

Other Planetary Observers now under study are a Lunar Geoscience Orbiter, a Mars Aeronomy Orbiter and several Mars Surface Probes, a Venus Atmospheric Probe, a Near-Earth Asteroid Rendezvous mission, and a Comet Intercept Sample Return mission.

Mission Planning

INTERNATIONAL HALLEY WATCH

More than 900 professional astronomers from 47 countries had joined the International Halley Watch (IHW) by year's end, as anticipation continued to build for the coming apparition of the most famous of comets.

The eight IHW networks of comet observers are being coordinated at JPL and the University of Erlangen–Nürnberg in West Germany. In addition to the professionals, some 350 experienced amateurs have committed themselves to observing for the IHW, and thousands more are expected to observe informally.

At year's end, Comet Halley was about as distant from the sun as the planet Jupiter. Continuing on the inbound leg of its 76-year orbit around the sun, Halley will make a relatively close approach to Earth on November 27, 1985, at a distance of 92.8 million kilometers; by that date, the comet will be visible through small telescopes.

Halley will pass closest to the sun (85.5 million kilometers) on February 9, 1986, and then closest to Earth (62.8 million kilometers) the following April 11. Naked-eye viewing from dark-sky sites should be possible by early 1986, perhaps in early January, and definitely in March and April. Unfortunately for those living in the Northern Hemisphere, the comet will be brightest when it is near the southern horizon.

Professional astronomers have been observing Halley with large telescopes since fall 1982. While these Halley studies continued, the IHW conducted a successful "trial run" with the short-period Comet Crommelin in March 1984 as a test of observational data handling and reporting procedures.

The IHW has been organized into eight disciplines—astrometry, infrared studies, large-scale phenomena, meteor studies, near-nucleus studies, photometry and polarimetry, radio science, and spectroscopy and spectrophotometry—of which four are now active. These ground-based studies of Halley are being coordinated with airborne, Earth-orbital, and spacecraft flyby observations. All results will be reported in a Halley archive at the end of the decade.

COMET RENDEZVOUS ASTEROID FLYBY

The Comet Rendezvous Asteroid Flyby (CRAF) will be the first of a proposed series of Mariner Mark II missions to the outer solar system. Detailed planning for CRAF is proceeding based on a planned start of the flight project in fiscal 1987.

Mariner Mark II is a concept for a new generation of low-cost spacecraft for scientific missions to comets, asteroids, and the outer planets. The engineering and science requirements for such missions are similar enough that hardware designs and software can be reused in most subsystems.

Scientists and mission planners have recommended Wild 2, a short-period comet believed to be in a largely pristine state, as the target for the CRAF mission. Launch in March 1991 from a space shuttle/Centaur combination would place the Mariner Mark II in the vicinity of Wild 2 in January 1995. The spacecraft would then fly alongside the comet, taking data for nearly three years, until about 150 days after the spacecraft and comet pass closest to the sun.

A bonus from the trajectory of the Wild 2 mission is a pass by the asteroid 476 Hedwig in September 1991, before the spacecraft's encounter with the comet.

A CRAF cost review in 1984 indicated that it would be possible to develop the mission for $300 million in fiscal 1984 dollars, thus meeting the goal set by NASA's Solar System Exploration Committee in its Core Mission report.

Advanced technology and development work on portions of the spacecraft made excellent progress during the year. Some breadboard and engineering models will be fabricated in 1985.

Although "inherited" technology will be used where practical, the CRAF spacecraft will employ several new subsystems, such as a power subsystem offering improved efficiency and a command and data subsystem that will take advantage of faster and more compact microprocessors and random-access memories. These and other new designs will measurably reduce cost, power requirements, and mass, and still give performance comparable to that of the Voyager and Galileo subsystems.

The project plans to release the scientific announcement of opportunity in mid-1985 and to select the payload in early 1986. The preliminary "strawman" payload showed that the CRAF mission and spacecraft design can indeed answer the basic science objectives set forth by NASA.

JPL is developing CRAF for NASA and conducting studies of subsequent Mariner Mark II missions, such as a Saturn Orbiter/Titan Probe and a Main-Belt Asteroid Rendezvous.

MARS SAMPLE RETURN

A Mars Sample Return mission is a prime candidate among the more ambitious "augmentation" missions being considered as follow-ons to the Core Program advocated by the NASA Solar System Exploration Committee.

In 1984, JPL conducted a joint study of such a mission with NASA's Johnson Space Center and Science Applications Incorporated. The baseline design evolved around a 1,200-kilogram planetary vehicle to be launched in two space shuttle loads and assembled in Earth orbit, possibly at the NASA Space Station. Planners envisioned:

- *A combination lander and orbiter that airbrakes into orbit about Mars.*
- *An entry vehicle that uses aeromaneuvering to land near two or three geologically interesting provinces.*
- *An autonomous rover that gathers a selected combination of rock and soil samples totaling 5 kilograms over a traverse of tens of kilometers.*
- *A Mars ascent vehicle that lifts the sample canister for an automated rendezvous and docking with the orbiter.*
- *Return of the sample to a receiving facility on the Space Station for initial analysis and quarantine.*

The study concluded that a scientifically rewarding set of samples could be gathered by such a mission. The primary technology needs were found in the areas of in-orbit assembly, autonomous surface roving, and automated rendezvous and docking. The study concentrated on a 1996 launch opportunity with return in 1999.

QUASAT

Quasat is a mission concept involving a large, free-flying radio telescope in Earth orbit, designed to observe astronomical radio sources simultaneously with ground telescopes. Complementary studies by JPL and the European Space Agency (ESA) have led to a baseline design for such a mission.

The technique of very long baseline interferometry (VLBI) would be used to synthesize a radio telescope with an aperture larger than the diameter of Earth. With VLBI data processing, measurements at widely separated antennas—in this case the orbiting Quasat and facilities on the ground—can be combined to simulate the resolving power of a giant antenna spanning the distance between them.

Such a configuration would yield images of extragalactic radio sources with greater resolution than has ever been achieved before. Quasat radio-frequency data would lead to a better understanding of the extreme high-energy events taking place at quasars, radio galaxies, active binary stars, and other distant celestial objects.

As now envisioned, Quasat would include a large deployable antenna 15 to 20 meters in diameter, with a precision pointing system accurate to within one minute of arc. NASA and ESA are considering plans to fly Quasat as a joint endeavor over a five-year mission lifetime in the mid-1990s.

Mission Support

AMPTE

JPL is playing a major role in supporting the Active Magnetospheric Particle Tracer Explorers (AMPTE), a three-spacecraft international study of the magnetic environment near Earth. The Laboratory has performed tracking, navigation, and

other tasks in support of the spacecraft since their launch in August 1984.

The joint U.S.–West German–British venture is designed to gather comprehensive new knowledge about the interactions of the solar wind and Earth's magnetic field. The German craft, the Ion Release Module (IRM), releases tracer materials from strategic points in its orbit; these materials, particles of lithium and barium, are detected by the U.S. spacecraft, the Charge Composition Explorer. The third craft, the United Kingdom Subsatellite, takes supporting measurements from a "station-keeping" position near the IRM.

JPL is the scene of all mission operations for the U.S. spacecraft. Data from the initial particle releases are in the process of being analyzed. One of the releases created an artificial "comet" shortly after Christmas Day, 1984.

FLIGHT PROJECTS SUPPORT

During 1984, the Flight Projects Support Office completed facilities modifications and other improvements in ground-data support systems for JPL deep-space missions. This past year, the office began development of an upgraded Space Flight Operations Control Center for future missions, oversaw startup of on-line operations of the Multimission Image Processing Laboratory, and completed modifications of the current Space Flight Operations Facility.

TEST FACILITIES

JPL's 25-foot Space Simulator conducted tests of several spacecraft in 1984, including the solar-thermal-vacuum evaluations of the Galileo flight spacecraft.

Major test programs were also conducted for two large communications satellites planned for geosynchronous Earth orbits—the Hughes/Comsat Intelsat VI and the European Space Agency's Olympus. The Olympus testing required the design and fabrication of two new spacecraft support fixtures, both products of the diverse engineering disciplines and services available within the Laboratory.

Science

BETA PICTORIS

Astronomers from JPL and the University of Arizona photographed evidence of a possible solar system around Beta Pictoris, a star 53 light-years from Earth. Employing special optical and computer techniques, the astronomers photographed a vast swarm of particles, called a circumstellar disk, surrounding the nearby star. The disk is the first of its kind to be seen clearly in astronomical photographs.

There is some evidence to suggest that planets could have formed around Beta Pictoris. The brightness of the star as seen through its disk indicates that the innermost particles of the disk may have been swept away, as would occur during the formation of planets. The astronomers cannot, however, determine yet if there are actually planets around Beta Pictoris.

The astronomers used a charge-coupled-device imaging system and a coronagraph attached to the 2.5-meter du Pont telescope at the Las Campanas Observatory in Chile. They chose Beta Pictoris for observation because earlier findings indicated the possibility of its having a circumstellar disk. Analysis of data from JPL's Infrared Astronomical Satellite had shown that Beta Pictoris and other, similar stars emit excessive amounts of infrared radiation, implying the existence of solid material orbiting around them.

THE RINGS OF URANUS

The astronomers responsible for the Beta Pictoris finding trained the same Las Campanas telescope on Uranus to obtain the first clear photographs of the planet's ring system.

An electronic camera system and computer processing revealed the nine rings to be composed of some of the darkest material found in the solar system. Photographing the rings proved difficult because of their darkness (they are as black as charcoal) and their closeness to the much brighter planet. Processing brought out details of the rings and revealed Uranus' five known moons.

JUPITER'S MOON IO

In the wake of the 1979 Voyager 1 and 2 encounters and in anticipation of the 1988 arrival of Galileo, JPL researchers continued their ground-based observations of Jupiter and its intriguing satellite Io. Studies like these help bridge the gap between more detailed measurements returned by planetary probes at widely spaced dates.

SODIUM CLOUD. Through telescopic studies from JPL's Table Mountain Observatory north of Los Angeles, observers acquired the most comprehensive set of images ever of the extended neutral sodium cloud surrounding Io. The images, produced with an intensified vidicon camera system, clearly demonstrate for the first time the complex, systematic variations of the cloud. The observations permit positive identification of true temporal changes, an important step toward use of the cloud as a long-term indicator of activities at Io and in the inner Jovian magnetosphere.

PLASMA TORUS. Refinements in Earth-based imaging techniques were used to extend the Voyager studies of the Jupiter/Io plasma torus—the tenuous ring of ionized sulfur that surrounds Jupiter and is believed to originate from material on Io. The observations were made at the Las Campanas Observatory in Chile with a coronagraph and charge-coupled-device detector. The large data set was used to show the Jovian sulfur nebula at different rotational phases.

VOLCANIC HOT SPOTS. Astronomers from JPL and the University of Hawaii have determined the longitudinal distribution of Io's volcanic hot spots from observations at the NASA Infrared Telescope Facility on Mauna Kea in Hawaii. These hot spots are observable from Earth because they emit a signal in the infrared that is quite distinct from that emitted by the colder areas of Io's surface. It is believed that these volcanoes depend

on tidal-induced motions that power a large heat flow through the surface of the satellite.

Repeated observations of Io as it traveled around Jupiter showed that the hot spots are strongly concentrated at a few longitudes on its surface. The areas of volcanism discovered by Voyager were still active, particularly the region around the feature known as Loki. This research also identified a new hot spot, not seen by Voyager, on the opposite hemisphere; the spot is larger than Loki and somewhat cooler.

VENUS GRAVITY

A JPL study provided a mathematical model of the global gravity field of Venus by using 40,000 Doppler observations acquired by tracking the Pioneer Venus Orbiter spacecraft. Deviations in the Venusian gravity field (compared to the gravity field in a theoretically homogeneous body) were shown to correlate with highs and lows in the planet's topography.

The amplitudes of the variations were shown to be about the same as those of Earth. Over large regions, however, the correlation of gravity to topography on Venus is unlike that on Earth, since the continents on Earth do not necessarily correspond to gravity highs. These findings indicate that differences in internal structure or processes exist between the two sister planets.

LUNAR RADAR OBSERVATIONS

New JPL radar observations of the moon were completed in 1984 with an improvement in mapping resolution by a factor of three over previous radar measurements. The observations, conducted over a three-year period, were acquired by the 430-megahertz radar system at Arecibo Observatory in Puerto Rico. A new limb-to-limb radarmetric calibration was conducted for the first time to produce a map of depolarized radar echoes from the moon.

HALLEY'S COMET

A collaborative program for observing comets was begun by JPL and Canadian astronomers using the 3.6-meter Canada–France–Hawaii Telescope (CFHT) on Mauna Kea in Hawaii. Images of Comet Halley, the first obtained through interference filters that were designated by the International Halley Watch, were taken in December 1984; analysis has been proceeding at JPL's Multimission Image Processing Laboratory.

The purpose of this program is to study the nature of cometary nuclei. This is best done while the comets are relatively inactive—that is, while they are at great distances from the sun. The outstanding observing conditions on Mauna Kea together with the large aperture of the CFHT are ideal for this kind of study.

In another joint effort, this between JPL and the University of Arizona, researchers began studies of Halley's dust-coma morphology. A new image-processing algorithm was developed to enhance features in the head of Halley as it appears in high-resolution photographs taken in 1910 at Mount Wilson Observatory during the comet's last appearance.

Boundaries of features are sharpened, and this permits better measurement of relative positions. The most striking features seen in the processed images are spiral jets of dust that appear to unwind from the sunlit side of the nucleus and evolve, on a time scale of days, into expanding envelopes.

The Deep Space Network (DSN) is a worldwide system for communicating with spacecraft exploring the solar system. The JPL-managed network of antennas is our link to these distant spacecraft, transmitting instructions to them and receiving the data they return from deep space.

Since its establishment in 1958 in support of the first U.S. satellite, Explorer 1, the DSN has grown to include nine deep-space antenna stations (eventually to number more than a dozen), a Network Operations Control Center and ground facilities at JPL, and ground communications linking all locations.

The stations are clustered at Deep Space Communications Complexes near Goldstone in California's Mojave Desert; near Madrid, Spain; and near Canberra, Australia. These widely separated locations ensure that spacecraft traveling beyond the rotating Earth are never out of view.

Each complex is equipped with a 64-meter-diameter antenna station; the antennas will soon undergo improvement in efficiency and expansion to 70 meters. The smaller antennas at each complex—26 and 34 meters—are being joined by new 34-meter high-efficiency antennas in anticipation of the greater communications challenges that lie ahead.

The complexes can also be teamed for scientific investigations with such techniques as very long baseline interferometry (VLBI), in which measurements made by two or more widely spaced antennas can be combined to obtain the resolving power of a giant antenna spanning the distance between them. Relatively new applications of the technique—such as mobile VLBI antennas for geodetic measurements and delta-VLBI for navigating spacecraft—promise further advances.

While deep space will always be its primary focus, the DSN has nearly completed preparations for assuming responsibility for all Earth orbiters not compatible with the Tracking and Data Relay Satellite System (TDRSS). The DSN will also provide emergency support for the tracking satellites themselves and for other spacecraft that would normally communicate through TDRSS. JPL's Office of Telecommunications and Data Acquisition (TDA) will oversee the implementation of these new DSN duties.

In other TDA activities, studies will continue in radio science, ground-based radar and radio astronomy, geodynamics, and the Search for Extraterrestrial Intelligence. TDA also manages the Laboratory's Institutional Computing and Information Services Office.

Mission Support

OPERATIONS

In 1984, the DSN continued to support the two Voyagers and seven Pioneer and Helios spacecraft, which are providing general science and engineering data. Support began for two other missions, each a collaboration with European partners: the International Cometary Explorer and the Active Magnetospheric Particle Tracer Explorers.

PIONEER. DSN support of the Pioneer missions, which are managed by NASA's Ames Research Center, continued in 1984. Pioneers 10 and 11 continued to return data on cosmic rays, solar-wind plasma, and magnetic-field variations from previously unexplored regions of the outer solar system. Pioneer 10, now beyond all the planets, remained the most distant man-made object, 5 billion kilometers from Earth, at the close of the year. At that distance, radio signals from the spacecraft take 4.7 hours to reach Earth.

Pioneer 12, in orbit around Venus, is imaging clouds and gathering data on the atmosphere and on the interaction between the Venusian ionosphere and the solar wind. Special calibrations were performed on the orbiter's ultraviolet spectrometer in preparation for planned Pioneer 12 observations of Comet Halley in early 1986.

The world's oldest functioning spacecraft, Pioneer 6, exceeded 19 years of operation by continuing to return solar weather data from its orbit between Earth and Venus.

AMPTE. Extensive testing and training were conducted in preparation for the August 1984 launch of the Active Magnetospheric Particle Tracer Explorers (AMPTE). After launch, the initial DSN acquisition and final orbit maneuvers for all three spacecraft were successfully supported by six deep-space stations and six stations of NASA's Goddard Spaceflight Tracking and Data Network (GSTDN).

In September, the DSN assisted with two AMPTE releases of experimental canisters into the solar wind. In December, a combination of DSN and GSTDN stations supported the third AMPTE release of particles into the solar wind—a barium release that created an artificial "comet" for scientists to study.

ICE. The DSN assumed primary responsibility in communications and navigational support for the International Cometary Explorer (ICE) at the beginning of 1984. The 64-meter antennas, arrayed with the 34-meter antennas, will provide primary telemetry support for the spacecraft's September 1985 encounter with Comet Giacobini-Zinner. The 64-meter antennas will also be used for ICE observations of Comet Halley in October 1985 and March 1986.

VOYAGER. The DSN provided extensive communications support with the 64-meter and 34-meter antennas, gathering general science and engineering data from Voyagers 1 and 2. In addition, the Network generated radiometric data for use in computing the Voyager 2 trajectory-correction maneuver in November 1984. Important flight data system tests and spacecraft calibrations were also supported periodically throughout the year in anticipation of the Uranus encounter in January 1986.

MARK IV-A IMPLEMENTATION

The DSN's Mark IV-A Implementation project made significant progress in 1984 toward its goal of

centralizing control of Network subsystems and increasing operational support capabilities for the Voyager 2 Uranus encounter.

In November 1984, the first Mark IV-A Signal Processing Center began operations at Goldstone. It includes new computers for each subsystem and, connecting them, a new local-area network (LAN). The LAN transmits all data between subsystems, thereby enabling centralized monitoring and control of the complex and permitting unattended operation of remote or antenna-mounted assemblies. Identical facilities are under development in Australia and Spain.

JPL also completed assembly and erection of two new 34-meter X-band high-efficiency antennas. These two antennas, located at Goldstone and Canberra, will provide a large part of the increased capability necessary for a successful Voyager encounter at Uranus.

The two 26-meter antennas from the Goddard network in Australia and Spain were relocated and reassembled near the sites of the DSN Signal Processing Centers in their respective countries. The antennas will become an operational part of the DSN in early 1985.

GOLDSTONE ANTENNA REHABILITATION

The 64-meter antenna at Goldstone was returned to service in June 1984 after being down a year for repairs. The repair work involved jacking the 6-million-pound structure free from its concrete pedestal. With the antenna resting on a temporary support structure, workers removed and replaced the top 7 feet of concrete and refurbished the hydraulic bearing on which the antenna rotates. The project was completed on time, within budget, and without a single lost-time accident.

ARRAYING FOR VOYAGER

The forthcoming Voyager 2 encounters with Uranus in 1986 and Neptune in 1989 will present a serious challenge in deep-space communications. During the Neptune encounter, for example, the Voyager X-band radio signal will be less than one-tenth as strong as it was at Jupiter in 1979 and less than one-half as strong as it will be at Uranus in 1986.

Improvements to the DSN, however, will complement improvements in the Voyager flight data system program, and significantly increase the potential data return. At the encounters, all DSN antennas at each longitude will be arrayed so that their combined collecting areas will determine the amount of signal capture and thus the potential for data return.

For Uranus, the new 34-meter high-efficiency antennas at Goldstone and Canberra will increase the potential data return by 25 percent. The Parkes Radio Telescope in Australia will join with the DSN to create a further 50-percent increase there.

For the Neptune encounter, the DSN will install a third 34-meter high-efficiency antenna, this one at Madrid, and upgrade the Network's three 64-meter antennas through improved reflector shaping and expansion to 70 meters in diameter. These improvements will effect a better than 50-percent increase in signal capture; design work for the upgrading was completed in 1984. The DSN will be joined again by the Parkes telescope and also by the National Radio Observatory's Very Large Array near Socorro, New Mexico, where the first of the required 28 new receiving assemblies was readied for testing.

Future Mission Support

DEEP-SPACE MISSIONS

The Deep Space Network is looking ahead, as well, to NASA and international missions still in planning or development.

HALLEY MISSIONS. In a continuing activity, engineers worked to implement L-band receiving capability for the DSN's 64-meter antennas. This new capability will be used to support the international Venus Balloon and Pathfinder efforts.

Two instrumented balloons are to be dropped into Venus's atmosphere by the Soviet Vega 1 and 2 spacecraft on their way to Comet Halley. The DSN will form the core of an international interferometric radio-navigation network for the balloons, which are to be deployed in June 1985. Under the Pathfinder project, the DSN will draw upon its navigational support of the Vegas near Halley to provide improved navigational data to the European Giotto mission, which is also bound for the famous comet.

The DSN is also supporting the Japanese MS-T5 and Planet-A missions, which, like the two Vegas and Giotto, are headed for Halley. The DSN helped track MS-T5 at its January 1985 launch and will support Planet-A with 26- and 34-meter antennas and provide the Japanese space agency with radiometric data and orbit determination support. Network antennas will support Planet-A and Giotto during their Halley encounters in the spring of 1986.

ULYSSES. Radio-frequency compatibility and command verification work was completed for the Ulysses transponder in preparation for DSN coverage of the May 1986 launch of the sun-bound spacecraft.

GALILEO. The DSN Compatibility Test Area at JPL supported Galileo test and integration activities throughout the year by providing an S-band uplink for commanding the spacecraft and S- and X-band downlinks for telemetry data.

The next phase of testing will use the Mark IV-A configuration of the Compatibility Test Area, with the spacecraft located in the solar thermal vacuum test chamber and the test teams in their operational positions in mission control. This arrangement will provide an environment representative of the actual flight conditions after the May 1986 launch; such testing will benefit both the Galileo mission operations teams and their counterparts in DSN operations.

VRM. The Venus Radar Mapper mission will require the DSN to receive and process data with the highest telemetry rate of any JPL

mission to date (268.8 kilobits per second). VRM will, in addition, be the first project user of a new navigational data type called narrowband differential very long baseline interferometry (delta-VLBI). This Doppler-equivalent data type is analogous to the range-equivalent wideband delta-VLBI data type that has already found application on the Voyager mission and in the planning for Galileo.

EARTH ORBITERS

The DSN completed plans for operational transfer of the 26-meter Goddard subnetwork in February 1985. At that time, the DSN will assume responsibility for supporting several existing Earth-orbiting missions that are not compatible with the Tracking and Data Relay Satellite System (TDRSS): the International Sun–Earth Explorers 1 and 2, Nimbus 7, and the Dynamics Explorer 1.

Under the new arrangement, the DSN will provide emergency support to TDRSS-supported missions and to the tracking satellites themselves. Also transferred will be the capability and responsibility to support a variety of geosynchronous satellites in their launch transfer orbits on the way to their permanent locations.

Technology Development

SPACECRAFT ORBITS

During the long cruise periods between encounters, the determination of a spacecraft's orbit traditionally relies on coherent Doppler and range data—that is, measurements of how the radio signal is changing in frequency and in transit time.

Several hours of continuous observations can provide an estimate of the spacecraft's angular position, and several weeks of observations an estimate of the angular velocity. Typically, many weeks of data representing several hundred hours of station time are used to estimate the orbit.

Recent work with Voyager radiometric data has shown that the techniques of differential very long baseline interferometry (delta-VLBI) can be used to achieve dramatic reductions in the amount of both data and tracking time necessary for cruise navigation.

Delta-VLBI data, which can be acquired in a noncoherent (listen-only) mode, provide direct high-accuracy measurements of spacecraft angular position. Delta-VLBI data, combined with infrequent coherent Doppler and range data, can improve estimates of spacecraft position and velocity by a factor of about two. These accuracies can be achieved with strategies that employ less than 5 percent of the traditional data with an accompanying ideal reduction in station time of more than one order of magnitude.

X-BAND UPLINK SYSTEM

An X-band transmitting and receiving station that is the forerunner of new systems for the DSN was designed and installed at the Goldstone 26-meter antenna. With a new 20-kilowatt transmitter and new temperature-controlled exciter and receiver modules, the automated system has been designed to maintain an extremely high frequency stability.

Working in conjunction with a new dual-frequency feedcone, the transmitting portion of the system was carefully measured to verify that it can meet its phase-stability goal of 5 parts in 10^{15} over a 1,000-second period. Such highly stable microwave and antenna systems are a necessary step in the attempt to detect the gravitational waves in space predicted by Einstein's general theory of relativity.

CODING FOR COMMUNICATIONS

DSN researchers demonstrated a major advance in coding schemes for deep-space telemetry in 1984.

To achieve reliable communications over a noisy deep-space channel, coding systems using a convolutional code and a Reed-Solomon code in series are usually suggested. The current baseline configuration (to be used on Voyager for the Uranus and Neptune encounters) has a regular convolutional code (constraint length 7, rate 1/2) combined with an 8-bit Reed-Solomon code.

The performance of a communication system can be improved by increasing the transmitter power, expanding the bandwidth, or increasing coding complexity.

With this last approach in mind, JPL researchers studied several classes of convolutional codes, the best of which were simulated on a realistic noisy channel. These experiments showed that a newly found convolutional inner code (constraint length 14, rate 1/5), combined with a 10-bit Reed-Solomon code, could achieve the desired performance with a signal-to-noise ratio of only 65 percent of that needed for the baseline.

CONTINENTAL DRIFT MEASUREMENTS

Distances between the Deep Space Network antenna sites in California, Spain, and Australia are regularly measured with very long baseline interferometry (VLBI) in an effort to minimize the effect of station location errors on spacecraft navigation.

One of the major problems in interpreting the observed time rate of change of these intercontinental distances has been inadequate modeling of atmospheric effects. New theoretical calibration techniques developed at JPL account for the average atmospheric contribution to the intercontinental length measurements, at the 1-centimeter level.

VLBI data spanning the years 1978 through 1984 give length rate measurements of +4 centimeters per year for the 8,400-kilometer California–Spain baseline, and −2 centimeters per year for the 10,600-kilometer California–Australia baseline. More precise estimates of these drift rates are expected in the next year, with improved modeling and more VLBI data.

INTRACOMPLEX STATION LOCATIONS

The precision with which spacecraft can be navigated by VLBI depends on the accuracy of both the radio reference source positions and the relative antenna locations.

Recent work has shown that phase-delay data can be used for

geodetic measurements over distances greater than 20 kilometers. Data of this type have been used to determine the relative station locations within the DSN complexes to a precision of 1 millimeter over distances as great as 22 kilometers—more than a factor of 10 improvement over previous results.

Using this type of data, it may be possible to navigate spacecraft with sufficient accuracy using local antenna arrays, rather than intercontinental arrays. Local arrays would offer the advantages of longer observing periods and freedom from many of the effects that degrade data with more widely separated antennas.

DIGITAL DESIGN TOOLS

User-designed custom integrated chips could be used effectively and economically in JPL's ground and spacecraft systems if a complete computer-assisted methodology were in place to support the design, fabrication, and testing of circuits. Such a system of tools is now being assembled for the custom design of very-large-scale integrated circuit (VLSI) chips for the DSN and other applications.

Many computer-aided-design tools are available for lower-level design, at the level of logical gates or transistors. Tools for design at higher levels of the functional hierarchy are, however, still in the experimental stage.

A key element of the VLSI design system is a tool called Ulysses, a language under development at JPL that will provide for the formal description and simulation of a design at all levels, from transistors to large functional blocks. An earlier version has been adopted elsewhere and used in the design of chips containing more than 100,000 transistors. The current version has been used at JPL to simulate the behavior of a prototype digital-filter chip containing 13,000 transistors for use in an X-band transponder on board a future spacecraft.

LASER DIODE ARRAYS

JPL is considering the use of semiconductor lasers as sources for space-based optical communication links for outer-planetary or interstellar missions. Offsetting the basic advantages of high efficiency, small size, and low weight is the fact that a single device cannot deliver the required power. A possible solution is to coherently combine the power of several semiconductor lasers that are fabricated monolithically on the same substrate.

DSN researchers fabricated a novel laser array to gain a better understanding of such factors as the coherence of the interacting lasers, the coupling strength and phase relationships among them, and wavelength selectivity and tuning. Further improvements in the modeling and development of new types of laser arrays are expected to yield a high-power device suitable for free-space optical communications.

Science

GEODYNAMICS

JPL's geodetic measurement program was expanded in 1984 to include additional sites in Alaska and Canada. The expanded network of sites is being used to monitor regional deformation in Alaska as well as tectonic movements between the North American and Pacific continental plates; previous measurements were concentrated in the southwestern United States.

The Alaska measurements represented the first time that JPL's mobile very long baseline interferometry (VLBI) systems had been deployed by air to remote sites outside the continental United States. Two of the mobile systems—each consisting of a small antenna and supporting electronics—were deployed; the sites were scattered over Alaska and southwestern and north-central Canada.

The measurements, which have application to earthquake studies and other geologic research, are to be repeated annually for NASA under the direction of the National Oceanic and Atmospheric Administration, which has accepted operational responsibility for the mobile VLBI systems.

El Niño Signature

Studies by JPL researchers suggest that, through its link with the atmosphere, the El Niño ocean-warming cycle of 1982 and 1983—which brought drastic changes in weather on both sides of the Pacific—had a detectable influence even on the motion of the solid Earth.

The studies demonstrated that changes in the angular momentum of the atmosphere are strongly coupled to changes in the rotation rate of the solid Earth, on time scales between about 30 days and 2 years.

The El Niño cycle is associated with a difference in atmospheric surface pressure between the eastern and western Pacific; this difference, known as the Southern Oscillation, reached a record value in January 1983. Starting late that month, when the El Niño Pacific warming event was near its peak, major anomalies in the wind fields resulted in record values for atmospheric angular momentum, accompanied by an anomaly in Earth's rotation rate. It was the most extreme Earth-slowing anomaly since 1970.

Lunar Laser Ranging

The Lunar Laser Ranging program took a major step this past year with the advent of high-accuracy multiple-station ranging. Analyses were performed with ranges determined by the transmission of laser pulses from McDonald Observatory in Texas and the CERGA site at Grasse, France, to retroreflectors placed on the moon's surface during the Apollo program.

The ability to model the lunar orbit over the 15 years since the Apollo mission has allowed studies of long-term variations in Earth's rotation, as well as precise determinations of observatory coordinates and Earth–moon dynamics. This science of the past 15 years was accomplished with ranges of 10 centimeters in accuracy. Most of these lunar-orbit measurements were made by a single station; the

accuracy of multistation measurements should lead to new insights.

SOLAR SYSTEM RADAR

The Goldstone Solar System Radar Facility has been substantially refurbished to make it more reliable and available. A new dual-channel X-band maser and radar receiving system was developed to provide dual-polarization observing capability. In addition, a new computer-based data-acquisition system was installed in the pedestal of the Goldstone 64-meter antenna, and a new radar-data processing system was installed at JPL. Observers will first use the improved facility for studies of Venus in early 1985; JPL will encourage more use by outside scientists.

SETI

JPL is developing and testing prototype instrumentation and observational strategies for the NASA Search for Extraterrestrial Intelligence (SETI) program, managed by the Ames Research Center.

The eventual goal is to carry out a full-scale search for radio signals of possible intelligent origin beyond our solar system. The approach is to conduct a microwave search using existing radiotelescopes and advanced spectral-analysis technology. The observational plan is twofold: a targeted search for weak signals, and an all-sky survey designed to detect stronger signals.

JPL has primary responsibility for the all-sky survey; according to current plans, the survey will use the DSN's 34-meter antennas. Prototype instrumentation, search algorithms, antenna scan patterns, and observing procedures are being tested at Goldstone using the 26-meter antenna. The signal processing instrumentation includes the DSN's 65,000-channel digital fast-Fourier-transform spectrum analyzer and a prototype 72,000-channel spectrum analyzer designed and built for SETI by Stanford University.

Computing Services

Progress continued in 1984, the second year of the Computing and Information Services System project. The primary objective continues to be the development of leading-edge computing, networking, and information services technology to meet JPL's growing needs.

A Phase 1 prototype of the Institutional Local-Area Network (ILAN) was completed in April, and an intersite trunk between JPL's main Oak Grove facility and its Foothill complex was installed in August. Plans and vendor contracts were completed for the Laboratory-wide installation of the ILAN cable system by the end of 1985, foreshortening the original schedule by two years.

Other activities of the Computing and Information Services Office included the development of a computer and network security program, improved processes for acquiring the personal computing hardware and software needed to meet rapidly growing demand, and a support system to improve office automation at JPL.

Support continued in 1984 for a relatively new initiative to study Earth as a system of interrelated, interacting parts, where the troposphere, stratosphere, oceans, ice, solid earth, and land surfaces function as a single, organic whole.

The Earth sciences have tended to treat the studies of these components as separate disciplines; the research guided by this approach has produced considerable knowledge of specific processes that govern such phenomena as winds, temperatures, and the chemistry of trace substances in the oceans.

Recent research, however, is paying increasing attention to questions that cross traditional disciplinary boundaries and require an understanding of the complicated linkages and feedbacks between the various domains. Such fundamental issues as the climatic effects of burning fossil fuels, the sensitivity of the atmosphere to fluorocarbons and other residues of an industrial society, and the causes of past class-wide extinctions of living species can be addressed only from a global perspective.

To meet this need, NASA has established the Earth System Sciences Committee (ESSC) for the purpose of developing a systematic strategy of observation and analyses of Earth processes.

The ESSC, now preparing a final report for release in early 1986, advocates a program of long-term, simultaneous, global observations. This study of such complex interactions as those between land and sea and air and sea will require cooperation among several U.S. and foreign agencies.

JPL, which has had an active Earth-sciences program for many years, will conduct several projects in support of ESSC objectives. For instance, development is proceeding on a number of spaceflight efforts designed to view Earth from space.

Two of these—the Ocean Topography Experiment (TOPEX) and the NASA Scatterometer (NSCAT)—will provide further data on air–sea interactions; TOPEX, a free flyer, and NSCAT, which is to fly on a Navy research satellite, will study ocean currents and winds, respectively. Other JPL efforts, such as the Atmospheric Trace Molecule Spectroscopy experiment and the Microwave Limb Sounder, will gather data on the atmosphere. Further in the future, JPL experiments may fly on the Earth Observing System platforms, companions to NASA's Space Station, to continue the work of these earlier missions.

Instrument development, data analysis and archiving, laboratory research, and theoretical studies will continue at JPL as part of the prospective international effort to improve our understanding of the Earth system.

Free-Flying Missions

JPL is conducting work in support of a number of free flyers, such as Earth-orbiting satellites and NASA's Space Station. The Laboratory's role ranges from overall project management of TOPEX to instrument development and technology support for other U.S. missions.

OCEAN TOPOGRAPHY EXPERIMENT

TOPEX is a proposed fiscal 1987 new start that would map the circulation of the world's oceans, using altimetric measurements of the sea surface. The Earth-orbiting satellite would be launched, at the earliest, in 1990.

Like the pioneering Seasat spacecraft before it, TOPEX would use an altimeter to measure ocean-surface height variations. TOPEX measurements, accurate to within 14 centimeters, would allow scientists to determine details of currents, eddies, and other features of ocean circulation. Analysis of the data would, in addition, reveal aspects of the geologic structure of the seafloor below.

Information gathered over three to five years would be used to determine the global ocean's average behavior and to calculate small-scale changes and fluctuations in circulation. This information is critical to understanding specific phenomena, such as the El Niño ocean-warming cycle of 1982 and 1983, as well as more general trends, such as the role of the oceans in the formation of weather and climate.

In 1984, JPL completed its collaborative mission study with Centre National d'Etudes Spatiales (CNES), the French space agency, which also intends to perform an ocean experiment. The study found that a combined NASA/CNES mission would be both feasible and desirable and could meet the objectives of each organization. The joint mission would be called TOPEX/Poseidon.

Three aerospace firms—Fairchild Industries, RCA Corporation, and Rockwell International—have completed satellite-definition contracts. Each of the companies has proposed an Earth-orbiting satellite for use as the TOPEX spacecraft; one would be chosen for the mission. The joint TOPEX/Poseidon would be designed for launch from a European Ariane 4 launcher and retrieval by a U.S. space shuttle. JPL is planning TOPEX for NASA and serves as project manager.

SCATTEROMETER

Winds play a crucial role in generating waves, in mixing the upper ocean, and in establishing and maintaining currents and large-scale ocean circulation; ocean winds also strongly influence the transfer of kinetic energy, heat, and moisture between sea and air—key parameters in the formation of weather and climate.

The NASA Scatterometer (NSCAT) will provide accurate, global wind-field data over a three-year period that partly overlaps the flights of the U.S. TOPEX and European ERS-1 oceanographic satellites. This data will be gathered over a swath of 600 kilometers on each side of the satellite's suborbital track; the swath width will provide near-global ocean coverage every two days.

In October 1984, after almost two years of study, NSCAT was initiated by JPL as a new NASA project. NSCAT is scheduled to join a complement of sensors aboard the Navy Remote Ocean Sensing System (NROSS) satellite, planned for launch in mid-1989.

In addition to the scatterometer sensor, JPL will provide a ground data processor that through research algorithms will process the raw scatterometer data into geophysical data products for use in oceanography and meteorology. This processed data will be made available within three days of receipt from the Navy.

Procurement of such major components as the radio, antenna, and traveling-wave tubes has begun.

MICROWAVE LIMB SOUNDER

The Microwave Limb Sounder (MLS) is one of 10 scientific instruments being developed for NASA's Upper Atmosphere Research Satellite (UARS), scheduled for space-shuttle launch in 1989. Now under development, the JPL instrument will contribute to a unique data base that will test and extend present understanding of Earth's upper-atmosphere chemistry.

From measurements of thermal emissions, the MLS will obtain vertical profiles of chlorine monoxide, ozone, water, and hydrogen peroxide, day and night, for a minimum of a year and a half. Vertical resolution will be about 4 kilometers; the MLS will also obtain pressure measurements accurate to an equivalent height of 0.1 kilometer.

A vibrational test model and a prototype model will be developed and fabricated at JPL; antenna reflectors and actuators will be procured from industry. A 183-gigahertz radiometer will be supplied by the Heriot-Watt University and the Rutherford Appleton Laboratory of the United Kingdom. JPL testing of key subsystem breadboards continued in 1984.

SPACE STATION

NASA's Space Station program began its definition phase with mission requirements studies, conceptual design, and the preparation of requests for proposal (RFP). The goal is to place a Space Station in Earth orbit by the early 1990s; the continuously inhabited facility would serve as a research laboratory and possibly a springboard for future missions beyond Earth.

JPL's 1984 contribution to this program drew on work for the accompanying Earth Observing System platforms. JPL helped to define the RFP requirements for these platforms associated with the manned station.

The Laboratory initiated a series of pricing and cost-modeling studies to assist the program in arriving at a useful and cost-effective design. The Caltech Division of the Humanities and Social Sciences is collaborating in the pricing studies, as are a number of other universities. Requirements were developed for technology and science missions that are JPL candidates for the Space Station, and JPL assisted in the integration of overall Space Station program mission requirements.

JPL continued to participate in planning the automation and robotics for the Space Station. Associated with this were technology development activities in teleoperation, automated power system management, and automated attitude control. Other Space Station technologies under development at JPL include software and management tools, sensors for rendezvous and docking, protective coatings, power and propulsion system models, and solar-thermal power system concentrators (a spin-off from JPL's terrestrial solar dynamic power research).

EARTH OBSERVING SYSTEM

In support of the Goddard Space Flight Center, JPL defined spacecraft configurations and payload packages for the Earth Observing System (EOS) program of NASA's Office of Space Science and Applications (OSSA). The free-flying unmanned EOS platforms would join the Space Station in low Earth orbit.

The platforms, which will be provided by the Space Station program, will conform to requirements developed in part by JPL. Two concepts were considered by JPL: a single, large platform and several smaller platforms; smaller multiple platforms were considered the most desirable.

JPL is defining parameters for imaging radar and high-resolution imaging spectrometer instruments, among others; all the instruments will be supplied by OSSA and matched with others as synergistic payload sets. Instruments from the National Oceanic and Atmospheric Administration and from commercial organizations may also fly on the platforms.

Since various instrument combinations are expected to be flown on a common platform, JPL has also defined a set of integrated services for specific payload packages. These services include specialized data processing, automated instrument interaction, and vibration isolation.

Space Shuttle Experiments

Two JPL experiments flew on space shuttles in 1984, and development proceeded on five other payloads scheduled for future missions. JPL has been using the shuttle almost since the beginning of its flight program—two JPL sensors were carried on the second flight of Columbia in 1981—and researchers at the Laboratory continue to study applications of the capabilities afforded by the reusable shuttle fleet.

SHUTTLE IMAGING RADAR

The second Shuttle Imaging Radar (SIR-B) flew aboard Challenger in October 1984, successfully achieving most of its goals despite problems with the shuttle and its supporting systems.

SIR-B was essentially an upgraded version of SIR-A; the addition of a tilt mechanism for the antenna allowed variable look angles between 15 and 60 degrees. This feature provided images of a specific target at different illuminations on successive days. The data will be used for stereo topographic mapping and for classification of surface features by their backscatter signatures as a function of incidence angle.

Other SIR-B improvements included a new digital data-handling system to increase dynamic range, an increase in resolution by a factor of two, and the addition of a calibration subsystem to increase the radiometric accuracy of the data.

An international team of more than 40 scientists participated in the experiment; they conducted studies in geology (including subsurface imaging), agriculture, hydrology, forestry, oceanography, and cartography. Most of the team members concurrently collected "ground truth" data at their sites for use in interpreting the radar imagery.

The mission encountered a number of problems, including loss of the primary digital data path between the shuttle and the ground, loss of command for long periods of time, and an electrical short in one of the antenna cables, which resulted in a loss of transmitter power.

Despite these problems, approximately 20 percent of the planned digital data and all of the planned optical data were collected during the eight-day mission. Production of imagery, at year's end, was proceeding at the rate of nearly 75 images per week; image quality is excellent.

Initial results of the investigations are to be presented at a symposium at JPL in the fall of 1985; final results will be published in 1986. The success of SIR-B may lead to a reflight in 1987, and work will commence on a follow-on instrument, SIR-C, planned for a 1989 mission. JPL manages the SIR series for NASA.

ATMOS

The Atmospheric Trace Molecule Spectroscopy (ATMOS) experiment will be flown on the Spacelab 3 mission in the spring of 1985 and on a series of later shuttle flights, the Earth Observation Missions, beginning in 1986.

ATMOS is a high-resolution interferometric spectrometer designed to obtain fundamental information on the chemistry and physics of the upper atmosphere. It will measure the extent to which the sun's radiation is absorbed by the atmosphere. From those measurements, the concentrations of the minor and trace molecular species that exist at altitudes between 15 and 120 kilometers can be determined.

The flight instrument, built by Honeywell Electro-Optics Division and managed by JPL, was successfully integrated into the Spacelab in January 1984; by year's end, all planned prelaunch testing had been completed.

A dedicated data-analysis facility for ATMOS was completed during the year. The facility's computer, array processors, and on-line memory are sufficient to handle the processing and analysis of the 10,000 infrared spectra expected from ATMOS during its maiden mission.

MATERIALS SCIENCE

Researchers at JPL are developing several shuttle experiments designed to test the behavior and properties of materials in the microgravity environment of Earth orbit.

ACES. The Acoustic Containerless Experiment System (ACES) is a reflyable space shuttle mid-deck payload that uses three-axis acoustic levitation for "containerless" processing of materials at high temperatures. During its initial flight in February 1984, ACES melted, manipulated, and then resolidified a sample of fluoride glass, a material that may one day be used in low-loss optical systems.

ACES is being refurbished and upgraded for a reflight in late 1985. Modifications include improved lighting of the sample for better video images, an extended experiment operating time, and improvements in acoustic control of the sample.

DROP DYNAMICS. The Drop Dynamics Module (DDM) will join ATMOS as part of Spacelab 3 in spring 1985. Like ACES, the experiment will use acoustic levitation techniques, in this case to position liquid drops in the near-absence of gravity. DDM data on the behavior of rotating or oscillating samples will contribute to fluid dynamics theory and help define guidelines for manufacturing materials in space.

The DDM is a sophisticated instrument designed for manned interaction. Two JPL scientists—Taylor Wang and Eugene Trinh—have been trained as payload specialists to fly with the DDM; Wang has been selected to conduct experiments during the first flight.

DDM reflights are scheduled on the first International Microgravity Laboratory (IML-1) mission in May 1987, as well as IML-2 in February 1989 and IML-3 in May 1990.

3AAL. The Three-Axis Acoustic Levitator (3AAL) will study the dynamic properties of compound fluid droplets and liquid shells of differing viscosities while they are acoustically suspended in a microgravity environment. The instrument is scheduled to fly in August 1985 as part of the second Materials Sciences Lab (MSL-2). The automated 3AAL can process and record data on multiple-fluid samples without human intervention. Data from 3AAL, which is to refly on MSL-3 and MSL-5, will help guide designers of future facilities for processing materials in space.

SUPERFLUID HELIUM. At year's end the Superfluid Helium Experiment (SFHe) had completed Level 4 integration testing at Kennedy Space Center in preparation for the Spacelab 2 mission in mid-1985. SFHe will investigate the mechanical and thermal properties of superfluid helium, a liquid that offers high performance and reliability in cryogenic cooling systems.

The experimental approach is to measure the motions of the liquid during small accelerations of the shuttle, as well as the minute temperature changes that result. Findings from the Spacelab 2 flight should add to the knowledge JPL gained while developing the cryogenic system for the Infrared Astronomical Satellite. The SFHe dewar system will be reflown in 1988 or 1989 as part of the Stanford University Superfluid Helium Lambda Point Experiment.

FORCE/TORQUE SENSOR

JPL and the Johnson Space Center initiated a joint experiment in December 1984 to demonstrate enhanced dexterity for the Remote Manipulator System (RMS), the shuttle's versatile robot arm.

The experiment, the RMS Force/ Torque Sensor, will measure and graphically display the three orthogonal forces and three orthogonal torques developed at the outer wrist joint of the RMS. Semiconductor strain gauges attached to the sensor will produce output readings from which the forces and torques can be computed; associated electronics will collect, digitize, and transmit the readings to an onboard microcomputer. The microcomputer will be coupled to a shuttle TV flight monitor to provide the RMS operator with an immediate graphic display of the forces and torques created as payloads are grappled and repositioned.

JPL will deliver hardware and software for this experiment in the summer of 1986 for a shuttle flight in 1987.

Science

Atmospheric Science

SULFURIC ACID. As part of their efforts to understand chemical processes occurring in the atmosphere, JPL researchers clarified the key steps in the gas-phase mechanism by which sulfur dioxide is oxidized to sulfuric acid in Earth's atmosphere.

The conclusion that a catalytic process is involved has important implications for the formation of acid rain in the lower atmosphere, as well as the chemistry in the stratosphere after the injection of sulfur compounds from volcanic eruptions. An example of the latter was the 1982 eruption of Mexico's El Chichon; observations of the resulting cloud by NASA's Solar Mesosphere Explorer satellite confirmed the behavior predicted by JPL laboratory studies.

Geology

AIRBORNE RADAR. The NASA/JPL airborne synthetic-aperture radar (SAR) system has achieved the capability of simultaneously collecting linear like-polarized (HH and VV) and cross-polarized (HV and VH) backscatter data.

During tests in 1984, digital recording and processing techniques produced multiple-polarization images that are perfectly registered. Images acquired in each of three polarization states can be encoded as red, green, and blue for color composite images, and differences in the polarization responses of different earth surface covers can be viewed simultaneously.

Analyses of the multipolarization radar data showed that they are extremely useful alone and in combination with data from other sensors for Earth-science applications. In particular, the SAR system provides a valuable source of remote-sensing information for geologic mapping and vegetation discrimination.

Images from Death Valley, California, Wind River Basin, Wyoming, and Savannah River Plant, South Carolina, for example, showed that the multiple-polarization data can aid in mapping surface deposits, sedimentary rocks, and forested environments, respectively.

Oceanography

CIRCULATION. Data from satellite altimeters have given researchers a new method for studying large-scale changes in ocean currents. This method employs the altimeter-measured heights of the sea surface and sea level at points where ascending and descending orbit ground tracks intersect.

The method, which is applicable to the TOPEX mission, has been applied to Seasat altimeter data to study the temporal evolution of the Antarctic Circumpolar Current (ACC), a strong eastward flow around Antarctica. Analysis of this data from the three-month mission of 1978 revealed a generally eastward acceleration of the ACC around the Southern Ocean with large eddy-like disturbances that appear to be associated with large ocean-bottom mountain ranges.

This analysis demonstrates the great potential of satellite altimetry for determining temporal variability in world ocean circulation; the measurement of such variability is basic to an understanding of the oceanographic elements of long-term weather changes.

ADVANCED TECHNOLOGY

The ability to develop and apply advanced technology is vital to JPL's goal of undertaking challenging new missions and improving performance and cost-effectiveness. The Laboratory sustains this ability in two ways.

First, JPL concentrates on six areas of emphasis:

- *Electronics and optics*
- *Energy conversion and thermal control*
- *Information processing*
- *Materials*
- *Sensors*
- *Structures*

In these areas, the Laboratory strives to maintain active new technology development and an outstanding staff.

Secondly, JPL pursues advanced technology thrusts, *which are characterized by the use of discretionary resources and the recruitment of new staff members to exploit emerging technological opportunities.*

JPL entered 1984 with two advanced technology thrusts—Optical Systems and the Advanced Microelectronics Program (AMP). During the year, the Laboratory initiated a third thrust, the Space Telerobotics Program (STP), in collaboration with members of the Caltech faculty. The objective of STP is to combine advanced electromechanical robotic technology with artificial intelligence research, thereby increasing the potential sophistication and complexity of future missions. JPL expects to submit a new initiative to NASA based on the STP planning phase that will be completed in 1985.

The mission of AMP is to conduct long-range applied research in the areas of computer architecture and subsystems, optoelectronics, advanced device concepts, and spaceborne very-large-scale integrated circuits (VLSI). The goal is to support JPL's NASA and Department of Defense missions and to make the Laboratory a center of excellence in these fields. Collaborative research with the Caltech campus is emphasized.

Programmatic highlights of 1984 included the appointment of a program director and the funding of 14 new AMP research initiatives through the JPL Director's Discretionary Fund. Two research highlights were the advances made in concurrent computing and associative computing memory.

CONCURRENT COMPUTING

Most experts agree that computer designs that transcend the traditional sequential architecture—central processor, memory, and input/output devices—will be required to satisfy projected future needs in high-speed computing.

In space exploration and aeronautics, for example, particular attention has been focused on such computationally intensive activities as imaging spectrometry, synthetic-aperture radar, and management of NASA's Space Station.

Fundamental limitations—the finite velocity of light, to name one—will restrict ultimate computing speeds to about 10 times those currently achievable unless further breakthroughs in computer architecture can be accomplished. One promising approach is the development of a computer architecture in which an array of communicating microprocessors work in parallel, or concurrently, on the solution of a problem. Some estimates indicate that parallel processing could increase computational power by a factor of a thousand or more.

JPL is playing a leading role in this emerging technology through the Caltech/JPL Hypercube project under AMP. The project is an outgrowth of pioneering work by Caltech Professors Charles Seitz and Geoffrey Fox.

A hypercube computer consists of an array of 2^n *microprocessors that are connected in such a way that each one communicates directly with* n *neighboring processors. (In the case of* $n = 4$*, for example, the array would contain 16 processors, each of which can communicate with four neighbors.) Each processor in the array is symmetrically equivalent and has its own memory. The processors perform their computations independently and asynchronously at the same time.*

The power of the hypercube grows in proportion to the number of processors in the array. Use of the most powerful mass-produced microprocessor chips may make possible the construction of hypercube computers many times more powerful than today's fastest supercomputers.

In 1984, the AMP hypercube team completed construction and installation of its Mark II machine. The machine consists of a 128-microprocessor array that offers 24 times the power of a Digital Equipment Corporation VAX 11/780, or about half the power of a Cray 1, today's most powerful sequential supercomputer. The cost of the hypercube is less than one-tenth that of equivalent sequential machines.

One of AMP's goals is to build, within three years, a Mark III hypercube 20 to 50 times more powerful than today's Cray 1.

In addition to the hardware engineering, AMP has organized a user group of more than 40 individual researchers from the campus, JPL, and local universities and industrial firms. The user group is developing new operating systems and applications software that will enhance the power of the hypercube in solving scientific and engineering problems. AMP intends to foster this program of software development in image processing, remote sensing data processing, modeling of planetary atmospheres, and expert systems for automatic spacecraft operations.

ASSOCIATIVE COMPUTING MEMORY

We all recognize a profound difference between the memory function of a digital computer and the memory function of our brains.

To access a piece of information in a computer, we must give the exact location in the memory where the information is to be found. Similarly, to store a piece of information, we must tell the computer which memory location is to receive the data. Any deviation from these protocols will cause an error.

By contrast, when we wish to recall information, we do not have to think about where that information is located in our brains. Remembered information is easily recalled if associated circumstances are provided (for example, What were you doing the day President Kennedy was shot?). Nor do we have to tell our brains which nerve cells to call upon when we want to remember our telephone number. We can recognize objects, sounds, or circumstances even when they do not correspond exactly to the original data.

Caltech Professor John Hopfield has been studying these remarkable recall properties of human memory and has proposed a theoretical model for a computer memory that is based on the architecture of the neural network in the brain. His calculations and computer simulations predict that the proposed network will have a kind of associative recall of information similar to our own. Working with Professor Hopfield, Dr. John Lambe of JPL has built an embodiment of the associative neural network, using solid-state electronic devices—a so-called associative computing memory (ACM).

In the JPL-built ACMs, a number (n) of solid-state amplifiers are connected through an interlocking feedback network of interconnected resistors. The amplifiers serve the function of the neurons in the brain, while the resistors represent the synapses between the neurons. JPL has built networks of up to 32 by 32 amplifiers in size and has demonstrated all of the functions predicted by the Hopfield model.

If an ACM has n amplifiers ("neurons"), it will store $n^2/4$ bits of information. This is a great economy over present technology, which requires at least one active device for each stored bit. In addition, the ACMs can recall stored information by stimulating the free inputs of the amplifiers with only a portion ("key") of the desired information or even a garbled or noisy version of it.

ACMs offer a third advantage. Since information is stored by the placement of a grid of resistors, the ACMs have an information density potentially much higher than that of any current memory device. Researchers predict information densities as high as 1 billion bits per square centimeter—the equivalent of the contents of 500 average-size books stored in the area of a postage stamp.

Each bit is stored in a delocalized form so that the ACMs will be very fault tolerant; as many as 10 percent of the connections could be broken before a significant recall error rate would occur.

JPL's current ACM work emphasizes the construction and testing of prototype networks, together with a search for resistor materials that will permit the projected high storage density. This work is supported at JPL by the Defense Advanced Research Projects Agency.

As a federally funded research and development center, JPL has a commitment to studying national problems in areas where its special capabilities can make a significant contribution. JPL meets this commitment by devoting a part of its resources to civil and defense programs that complement its primary work for NASA.

Since 1981, the Laboratory has conducted work for the U.S. Air Force, Army, and Navy, and the Defense Advanced Research Projects Agency. JPL's Defense Programs Office has identified three major fields for future emphasis: autonomous systems, remote sensing, and information systems.

Generally speaking, the goal is to seek projects that will complement the Laboratory's more traditional NASA responsibilities while adding to the vitality of JPL as an institution.

To its sponsors, JPL offers mature skills in systems engineering, advanced technology, and science. To JPL, new opportunities in defense offer a means of strengthening the skill base that is so essential to the civilian space program.

Arroyo Center

Transfer of the Arroyo Center, the analysis center established by JPL for the U.S. Army, was completed shortly after the end of the year. The organization will continue as a new operating division of the Rand Corporation.

JPL initiated development of the Arroyo Center in July 1982 to provide a special long-term analysis and study capability for the Army. At Rand, the organization will continue to function as an independent technology and policy study center for the Army, with an emphasis on long-term, high-priority issues.

The move fulfilled the commitment of JPL and Caltech to develop the center and transfer it upon completion of its establishment and staffing. All Arroyo Center studies not completed at JPL will continue at Rand, although some may be reoriented.

One Arroyo Center study assessed future trends for the Army—specifically, projections of military, political, social, and technological activities in the year 2000. Other studies addressed the utility of remote sensing as a means of detecting treaty violations, in particular in the area of chemical warfare; the Army's need for improved weather monitoring; and the effectiveness of Army training exercises.

ASAS/ENSCE

The past year brought continued development of the All Source Analysis System/Enemy Situation Correlation Element (ASAS/ENSCE) project. Its mission is to field a baseline data-processing system designed to satisfy U.S. Army and Air Force tactical intelligence needs in the early 1990s. Joint sponsors are the Army and the Air Force.

ASAS/ENSCE will employ computer workstations housed in protected and highly mobile field modules. The system will be capable of receiving large quantities of intelligence data and analyzing and prioritizing it. The system will then subject the data to automated processing and display for use by battlefield commanders.

JPL has conducted project definition and systems architecture engineering. The Laboratory is performing software development and is working with its major contractors in implementing design, manufacturing, hardware acquisition, software integration, testing and training, and field support. JPL will also incorporate improved message-handling capabilities and ensure, through a product improvement effort for the sponsors, that the system design and architecture will evolve as planned.

The system design and implementation allow for the deployment of an early capability for the Army's Light Divisions. These early deliveries, configured for transport on highly mobile 1¼-ton trucks, consist of modules that are elements of a complete ASAS/ENSCE system. An early version of an ASAS interface module was successfully tested during the Border Star military exercises in Texas in early 1985.

In other 1984 activities, considerable progress was made on systems and applications software, and the project awarded several contracts to industry. The contracts cover production of communications and shelters for automated data-processing equipment, development of selected portions of the data-analysis applications software, and performance of the system test and integration activities.

Army Activities

JPL continued work on a number of other tasks for the U.S. Army in 1984, covering a wide range of technical disciplines.

UNMANNED AERIAL VEHICLES

The Airborne Surveillance Sensor Test Bed (ASSET) task developed and demonstrated an infrared and a visual sensor on a small piloted aircraft that simulated an unmanned aerial vehicle.

The ASSET system was successfully operated by Army personnel in a brigade-level exercise in which the sensors provided real-time scenes to the ground for battlefield surveillance under both day and night conditions and in various weather conditions. The image data and the aircraft location were transmitted to a ground control station through a mountaintop relay station; this arrangement allowed for over-the-horizon data transmission between the aircraft and ground control at the command center. The ground control station, upon receipt of the image and aircraft data, determined the position of the scene and displayed the image with superimposed position information on video monitors. The commander was then in a position to take action against targets identified by ASSET.

JPL delivered the basic ASSET system within six months after receiving program funding. Plans call for the system to be upgraded in 1985

with image enhancement, a passive millimeter-wave sensor, and relay systems that will extend range.

In another effort, JPL neared completion of its support of an Army surveillance aircraft called the Aquila. JPL is supporting the Aquila program office by providing technical and management planning, reviews, and assessments in specialized areas. These areas include software development, flight controls, and mission payloads. In June, JPL completed its design and testing of a low-cost, secure alternative data link for the Aquila system.

MICROELECTRONICS AND COMPUTING

The Army Model Improvement Program (AMIP) is supporting the Army in concurrent processing research and development using the Caltech "hypercube" computer design and associated hardware and software. The aim is to help users effectively apply and understand the outputs and results of many diversely developed Army computer models. One goal is convenient access to data used within the models. Close alliance between AMIP and the Caltech/JPL hypercube team led to notable progress during the year and resulted in a system for the Mark II version of the hypercube machine.

ADVANCED MATERIALS

In a project for the Army, JPL is working to develop advanced materials and fabrication techniques for lightweight armor. JPL completed designs of highly efficient weight- and space-saving systems made of ceramic appliqués, and readied an advanced hull model for structural testing. The project to date has made excellent progress in both structures and materials, and information is being disseminated to the sponsor and to industry.

SIMULATION AND TRAINING

JPL is developing a comprehensive training system that would better prepare Army soldiers for combat. Using a wide variety of technological skills, the system seeks to simulate accurately and safely the environmental effects of artillery fire and other combat elements for field training exercises.

Safety has been the principal concern throughout the four years of development. The technological challenge has been to provide an effective training system that is within safety constraints while being of reasonable fidelity and acceptable cost. A major upgrading of the system will incorporate improvements suggested by the results of early testing. The goal is to transfer the proof-of-concept designs to the sponsor and industry for the production of a complete system suitable for full Army use.

Space Activities

JPL is supporting the defense community in several continuing space activities.

IMPS

Definition studies for a mission known as the Interactions Measurements Payload for Shuttle (IMPS) were completed for the Air Force Geophysics Laboratory (AFGL). The Air Force's goal is to obtain design criteria for satellites to be launched into highly inclined orbits, where the polar/auroral environment is known to be severe. IMPS, to be launched between 1988 and 1990, would provide the required science and engineering data on hazards to astronauts and equipment in this environment.

JPL will serve as instrument-system manager for the AFGL and will work with Air Force laboratories that are providing some of the experiments; JPL will also provide one or more experiments for IMPS. The implementation phase is expected to begin in early 1985.

DATA SYSTEMS

JPL is supporting the Air Force in command, control, and communications technology by evaluating the use of microprocessors and local-area networks for improved monitoring of air transport missions. The goal is to provide more timely information to planners regulating the flow of Air Force transport activities. Intelligent workstations and distributed processing will help provide this more timely information by improving communications and reducing redundant effort. The definition phase is complete and implementation is under way.

CIVIL PROGRAMS

Since the 1960s, JPL has been applying its many technological skills, gained mostly in the pursuit of goals in space, to the solution of problems closer to home. Studies in such areas as energy, transportation, and medicine have occupied researchers at the Laboratory for many years and continue today under the general heading of Civil Programs.

Most of this work has been sponsored by federal agencies—principally the Department of Energy, the Department of Transportation, and the National Institutes of Health—or by individual industrial associations and firms. NASA also contributes directly through its Technology Utilization Office and Life Sciences Office.

Over the years, the Civil Programs have encompassed applications in biomedical technology, public safety, public transportation, and industrial processes. The effort peaked in the latter half of the 1970s, as researchers intensified their search for alternatives to imported energy and nonrenewable fossil fuels. Today, because national interest in "the energy problem" has declined, the mix of work is evolving again, and new opportunities in other fields have arisen.

Even as the Civil Programs evolve, the objective remains unchanged: to make selected application of the Laboratory's technological and managerial capabilities in response to significant national needs within the public sector.

JPL is working toward this goal by supporting federal research and development programs and by assisting U.S. industry in areas of technological innovation.

Emphasis will continue on research and development of energy technology, although the scope of JPL's work for the Department of Energy is down from its 1970s peak. The development of economical photovoltaic technology has been a particular area of interest.

Other areas of emphasis over the next several years include the life sciences and other biomedical engineering tasks; aviation and, in particular, work for the Federal Aviation Administration in upgrading the National Airspace System; and an increasing program in environmental technology.

The Civil Programs will continue to apply JPL's considerable technological and system skills, together with its project-management experience, to a wide variety of problems in the public sector.

Alternative Energy

ENERGY SYSTEMS TECHNOLOGY

JPL is studying the application of optical-fiber technology to electrical power distribution systems, under work funded by the U.S. Department of Energy (DOE).

DOE's goal is to develop a power distribution grid that could monitor its own status, use this information to decide on an optimal grid configuration, and reorganize itself to that configuration even if central control were lost.

Work at JPL in the area of optical-fiber sensors includes the development of sensors that are powered over optical fibers, sensors that are queried over optical fibers, optically controlled devices, optical fault location, and distributed intelligence. Distributed intelligence would allow the grid to configure itself for optimal operation if communications to the main control center were lost.

PHOTOVOLTAICS

The aim of the Flat-Plate Solar Array (FSA) project is to develop technologies that will lead to the economical generation of large quantities of electricity using photovoltaic panels. Through a combination of in-house work and subcontracts with universities, other laboratories, and industry, the FSA has helped define a clear-cut path by which that goal can be achieved.

In one FSA effort, researchers have now fully developed a process for manufacturing inexpensive, high-quality silicon—the basic raw material needed for the mass-production of photovoltaic cells. This advance, now being converted to industrial practice, reduces the cost of silicon fourfold and should contribute significantly toward reducing the cost of the final product.

Other researchers are working to automate and refine processes that grow dendritic-web silicon ribbon from the molten raw material. They have succeeded in achieving a marked increase in the rate at which the sheet material can be produced. The full development of these processes should lead to cost savings at this manufacturing step.

The FSA has achieved a number of other improvements, each resulting in further decreases in manufacturing costs: alternate methods for making sheet silicon from monocrystalline materials; new processes for the surface treatment, doping, and annealing of silicon wafers; and new methods for the attachment of contacts and the assembly of silicon cells into finished modules.

Another great economy is promised by a process under current study: the production of cells with efficiencies of 18 to 20 percent, which are very high compared to the 12 to 14 percent efficiencies of today's cells.

At the same time, work was begun on the engineering development necessary to determine whether less costly but less efficient amorphous silicon cells can be made in sizes and configurations useful in high-power applications, while still providing long life and reliability in the field.

Despite this progress, there remains the need for a new generation of modules that cost even less

to produce, have higher efficiencies, and provide performance lifetimes as great as 30 years.

SOLAR-THERMAL POWER SYSTEMS

In 1984, JPL completed its project to develop solar-thermal parabolic dish systems for the generation of electric power. At the Edwards Test Site in the Mojave Desert, JPL demonstrated system efficiencies approaching 30 percent and received firm expressions of intent by several industrial organizations to commercialize the technology; production facilities are planned as a first step. The remaining operations and equipment have been transferred to DOE's Sandia National Laboratories in Albuquerque, New Mexico.

This strong industry interest fulfills JPL's original project objective: to establish an industrial base for solar-thermal electric power systems.

Energy Conservation

BIOCATALYSIS RESEARCH

With DOE funding, JPL is supporting applied research and development aimed at establishing the technology base needed by the chemical process industry to develop cost-competitive products based on renewable energy sources.

As a part of this effort, JPL researchers in biocatalysis technology are searching for solutions to the basic technical barriers that have impeded the use of continuous biochemical production processes. A major objective is to provide scale-up and design data for large-volume, biologically facilitated chemical production processes that are more energy efficient than conventional processes.

JPL's work in this field has grown steadily over the past two years and is gaining increasing attention from industry, academia, and government programs as a base for applied research in bioprocess engineering. As an example, one JPL request for a proposal for advanced bioprocess concepts attracted more than 20 proposals.

The last year's accomplishments in this field include:

- The discovery of mutant fungi that produce and secrete relatively large quantities of the enzyme that plays a major role in biologically converting cellulose into glucose.
- An experimentally verified new method of introducing genetic traits directly into the chromosomes of microorganisms.
- From researchers studying the mathematical modeling of cellular processes, advances that will permit the performance of different classes of bioreactors to be calculated.

Environmental Technology

FOREST FIRE DETECTION

JPL has completed one project and begun a second for the U.S. Forest Service, each with the aim of helping detect and map forest fires.

For the first project, JPL designed and built an advanced infrared detection instrument called FLAME—Fire Logistics Airborne Mapping Equipment. The instrument, now in use by the Forest Service, can detect a "hot spot" of approximately one square foot from an altitude of 15,000 feet.

FLAME provided excellent thermal infrared (IR) imagery of large forest fires during the 1984 fire season. Interpretation of the images allowed the Forest Service to determine both fire perimeters and associated hot spots.

A related follow-on to FLAME is the Forest Fire Advanced System Technology (FFAST) study. FFAST, an advanced fire detection and mapping system, is currently in the conceptual design phase. FFAST will incorporate emerging technologies as they become available, including IR linear arrays, mobile satellite communications, and automatic georeferencing to a map base.

The system will provide georeferenced forest-fire intensity and location information to the fire camp within 30 minutes of the IR flight. Today, two to four hours or more may elapse before even the raw, uncorrected IR imagery can be delivered to the fire camp.

FFAST will provide significant savings of natural resources and the human and mechanical resources required to fight fires. The project is jointly funded by the Forest Service and the NASA Technology Utilization Office.

Biomedical Technology

LASER ANGIOPLASTY

Laser physicists at JPL and cardiologists at Cedars-Sinai Hospital in Los Angeles have demonstrated the use of a pulsed ultraviolet xenon-chloride (XeCl) excimer laser developed at JPL to clean out clogged arteries without damaging the blood vessel walls. Laser treatment of clogged arteries, as an alternative to open-heart surgery, is the goal of the JPL-Cedars collaboration.

The cleaning of blocked arteries using laser radiation delivered through a narrow-diameter fiber-optic catheter has been previously demonstrated and is being actively studied as an alternative to heart-bypass surgery. However, laser angioplasty using conventional medical lasers operating at visible or infrared wavelengths has been plagued by the lack of precise control of tissue ablation and by severe thermal burn damage to the tissue edges.

Results with the pulsed ultraviolet XeCl excimer laser, which ablates tissue by photodecomposition rather than a photothermal mechanism, demonstrate that precise control of the depth of tissue removal without thermal damage can be achieved.

BIOLOGICAL RADIATION MONITOR

NASA's space shuttles typically fly at low altitudes and in equatorial orbits; the advent of orbits at inclinations higher to the equator,

and even polar orbits, poses an additional hazard to flight crews because of the increased flux of high-energy particle radiation (HZE) from cosmic rays.

The effects of such cosmic rays on living tissues and genetic material is not fully understood. This past year, JPL began work in this important area of study, specifically trying to determine the physical, chemical, and biological consequences of HZE radiation.

Two biological systems were chosen for characterization of HZE effects: the bacterial DNA plasmid pBR322 and the nematode Caenorhabditis elegans. *The DNA plasmid is used with a sensitive high-pressure liquid chromatography method for chemical measurements of radiation-induced breaks in the DNA strands; the nematode is used for measurements of radiation-induced genetic mutations in a simple animal.*

Gamma rays from cobalt-60 are used to establish baseline values for DNA and genetic damage. Simulation of cosmic rays is provided by accelerated ions produced at the Lawrence Berkeley Laboratory's BEVALAC accelerator.

Experiments to date have provided dose-response data for several classes of mutants and double-stranded breaks in DNA. Ultimately, radiation damage caused by actual cosmic rays will be characterized during flight experiments involving DNA and nematode specimens.

PROSTHETIC IMPLANTS

Prosthetic materials and devices are implanted to overcome or alleviate a wide variety of problems in clinical medicine. More than 250,000 vascular replacement devices are implanted every year in the United States alone.

Currently available large-diameter vascular replacements are generally considered satisfactory. Yet vascular prostheses of small internal diameter (less than 6 millimeters), such as those used for coronary arteries and peripheral vessels, are still largely unproved and require further development before widespread clinical use can begin.

A new JPL development may help advance the technology. Ion beams developed for advanced spacecraft propulsion systems have been used with photolithographic masking techniques to etch microscopic patterns in the surface of Teflon. These highly ordered specific surface morphologies can be used to obtain a microtextured blood interface surface for use in cardiovascular prostheses. It is hoped that this advance will improve the strength of adhesion between the prosthesis and the cell layer that the body deposits over the surface of the device after surgery, thus improving the long-term success of such implants.

Aviation

NATIONAL AIRSPACE SYSTEM

The Federal Aviation Administration (FAA) is conducting an extensive multibillion-dollar upgrading of the entire National Airspace System (NAS), which controls air-traffic operations around the country. The FAA plans to replace virtually all of the components of the system with new elements employing the most modern technology.

JPL has been assigned responsibility for two of the subsystems to be installed as part of the 10-year-long upgrading. The challenge throughout this period of work will be to accomplish the substitutions with total reliability and without any impact on the continuing operations of the system.

One of the subsystems assigned to JPL is the Voice Switching and Control System (VSCS), which will provide integrated radio and telephone/intercom services for the FAA's Area Control Facilities. Touch panels will be integrated into the traffic controllers' sector suite consoles. The computerized VSCS is to be expandable in size and capability to meet increasing demands as other elements of the NAS are upgraded.

JPL is providing systems engineering and technical assistance to the FAA in procuring the advanced hardware from industry; the Laboratory is also contributing improved technology for future upgradings.

The second subsystem is the Central Weather Processor (CWP), which provides data processing and display. The goal is to improve safety and efficiency through the rapid collection and analysis of diverse elements of weather data, and the subsequent dissemination of weather information to controllers and pilots.

The CWP will maintain an extensive base of current graphic and alphanumeric weather data, including information from satellites, radar, pilot reports, and the National Weather Service. Meteorologists will be able to call upon extensive algorithms that allow use of this interactive computer workstation for improved weather forecasting.

JPL designers are stressing not only reliability, but a flexibility that will assure adaptation to future changes in external interfaces.

Research and development costs for the fiscal year ending in September 1984 were $506 million, a 20.3-percent increase from fiscal 1983.

Costs for NASA-funded activities rose 12.5 percent to $372 million. Civil Programs costs declined to $38 million, down 5.0 percent from the previous year, while tasks for the Department of Defense amounted to $85 million, an increase of 77.1 percent.

The JPL work force increased during the year to 5,142. The figures for the past two years were 4,590 (1982) and 4,907 (1983).

Procurement obligations during fiscal 1984 totaled $320 million, a 52-percent increase from the previous year. The total included nearly $298 million to business firms; of that, obligations amounted to $113 million to small business and $9.7 million to minority business.

Facilities

A Long-Range Facilities Plan adopted in 1984 will guide the modernization and expansion of facilities at JPL's Oak Grove site over the next 15 to 20 years. Key objectives are the return to Oak Grove of those people and activities now housed in leased space, replacement of substandard facilities, and reduction of the average housing density from its present level.

A significant step toward these objectives was achieved at midyear when NASA and Congress approved construction of a major technical office structure, the Central Engineering Building. The building is to be financed by Caltech; the 170,000-square-foot facility will become NASA property upon repayment of the Caltech investment. Occupancy is scheduled for mid-1986.

Another key piece of the plan is a new Earth and Space Sciences Laboratory, which is included in NASA's fiscal 1985 appropriation. The 97,000-square-foot building is scheduled for occupancy in late 1986.

Ground was broken in July 1984 for the first new building in the plan, the Frequency Standards Laboratory. Construction of the 14,000-square-foot structure was well under way by year's end.

Discretionary Funds

DIRECTOR'S FUND

The Director's Discretionary Fund (DDF) awarded start-up monies to 20 new tasks in 1984 and second-year increments to two earlier-sponsored tasks. The recipients were chosen from 100 proposals.

DDF funding continues to provide the major resource at JPL for support of innovative and seed efforts in promising areas of science and engineering for which conventional funding is not available. Since 1980, the DDF has been funded at $1 million per year. In recognition of the unique importance of this resource, however, NASA has agreed to increase funding to $2 million in 1985, and perhaps to a still higher level in 1986.

Collaborative work with faculty and students at Caltech and other universities is strongly encouraged, both for its own sake and as a source of fresh stimulation to exploratory investigations. Faculty collaborators were involved in 10 of the new tasks and in both of the tasks that gained second-year awards from the DDF.

PRESIDENT'S FUND

The Caltech President's Fund provides a second, though smaller, source of discretionary funding, through which 21 new tasks were started in 1984.

The special aim of the Caltech-administered fund is to encourage faculty and student participation in research activities of importance to JPL. At the same time, projects supported by the President's Fund give JPL staff members opportunities for close collaborative contact with able research workers from the university community.

Funds are provided by Caltech and NASA on a matching basis. In 1984, NASA increased its commitment under this arrangement from $350,000 to $500,000 per year.

As with the DDF, proposals for President's Fund support are solicited every year, and there are always several times as many worthy candidates as can be supported with the resources available. The new tasks in 1984 involve, besides Caltech, the University of Southern California, the University of Washington, Stanford University, and four campuses of the University of California.

Engineering and Review

The Office of Engineering and Review manages the Laboratory's reliability and quality-assurance activities in support of major spaceflight projects and experiments. During 1984, the office supported 19 spaceflight projects and experiments and participated in the planning of 17 potential new spaceflight efforts.

In an effort to assure the reliability of advanced microelectronic components, the office has defined a long-term program of equipment and facility modernization. During 1984, the office procured and placed into operation a new scanning electron microscope with an energy-dispersive spectrometer and a new integrated-circuit memory tester.

Several test programs were performed using high-energy particle accelerators in a continuing study of the susceptibility of large-scale integrated circuits to "single-event upset" (SEU) by cosmic rays. As a result of this experience, JPL was given a leadership role in a new NASA ground-test program that will evaluate the resistance of new large-scale integrated circuits to SEU. This field of study has particular application to advanced microelectronic components that are candidates for spaceflight use.

The Office of Engineering and Review also manages JPL's review

assessment and engineering standards programs. During 1984, the Laboratory conducted 33 formal reviews that were monitored by the office to assess the quality of JPL's formal review process. An approved reference list of more than 3,200 engineering standards in use at JPL was compiled and published. The standards are grouped into four main categories: engineering management, technical, government, and industry; eventually, the entire set will be available on microfilm as part of an Engineering Standards Library.

NASA Honor Awards

The NASA Honor Awards program gives special recognition to outstanding individual and team efforts. In 1984, the program honored 25 individuals and eight groups at JPL, many for contributions to the successful Infrared Astronomical Satellite (IRAS) mission in 1983. (A large number of other individuals and teams from elsewhere in the United States, from England, and from the Netherlands also received NASA Honor Awards for their work on the IRAS mission.) The JPL recipients were as follows:

NASA Outstanding Leadership Medal

Moustafa T. Chahine
W Gene Giberson
Gerald M. Smith

NASA Exceptional Scientific Achievement Medal

Hartmut H Aumann
Alan Rembaum

NASA Exceptional Engineering Achievement Medal

Dan A. Bathker
Walter E. Brown, Jr
Peter V Mason

NASA Equal Employment Opportunity Medal

Willis G Meeks

NASA Exceptional Service Medal

Waldo J Castellana, Thomas J Chester, Harry E Cotrill, John H Duxbury, Robert Frazer, John E Fuhrman, Albert R Hibbs, Jay A. Holladay, George C. Hsu, J Charles Klose, William I McLaughlin, Carl D Newby, William E Porter, Kumar N R. Ramohalli, Phillip A Tardani, Robert H White

NASA Group Achievement Award

Microwave Sounder Unit Development Team
Solar Thermal Parabolic Dish Project Team
IRAS Mission Operations Team
IRAS Project Staff, Integration, and Test Team
IRAS Telescope Development and Test Team
IRAS Focal Plane Redesign Team
IRAS Mission Scientific Data Analysis System Development and Operations Team
IRAS Joint Infrared Science Working Group

Visiting Scientists

The Distinguished Visiting Scientist program, initiated in 1979, brings academicians to the Laboratory from around the world to work with JPL scientists, technologists, and management. Participants in 1984 were Professors Michael Longuet-Higgins of England; Jacques Blamont and Ichtiaque Rasool of France; Hugo Fechtig and Klaus Hasselmann of Germany; and Syun Akasofu, David Atlas, Richard Goody, Lewis Kaplan, Aden Meinel, Marjorie Meinel, Peter Niiler, and Eugene Shoemaker of the United States.

Senior Research Scientists and Engineers

In 1979, JPL established a new grade of senior research scientist/engineer as a means of giving special recognition and promotion to outstanding individual research achievers.

Appointees must have demonstrated the ability to meet the research requirements typical of the position of full professor at a leading university, as evidenced by outside peer review. Appointment also depends upon the individual's active participation in programs related to the research and institutional goals of the Laboratory.

In establishing this grade, JPL is responding to the need to attract and retain outstanding researchers equivalent to those at leading teaching institutions of science and technology. As leaders in their fields, these senior research scientists and engineers can help establish JPL goals in key areas of study that are of national importance.

To date, 36 individuals have achieved this grade. Appointments are made by the Laboratory director in consultation with the chief scientist. Following is a list of the appointees and their field of specialization.

SENIOR RESEARCH SCIENTISTS

John D. Anderson
Radio science, experimental relativity

Lloyd H. Back
Transport and reactive processes

Giuseppe Bertani
Molecular genetics

Moustafa T Chahine
Atmospheric science

Terry Cole
Chemical physics

William B DeMore
Atmospheric chemistry

Charles Elachi
Radar remote sensing science

Frank B. Estabrook
Relativity, applied mathematics

Alexander F H Goetz
Geologic remote sensing

Richard M. Goldstein
Planetary radar

Samuel Gulkis
Planetary radio astronomy

Amitava Gupta
Photochemistry

E David Hinkley
Laser monitoring of the atmosphere

Westley T. Huntress, Jr.
Chemical physics, atmospheric science

Allan S Jacobson
Gamma ray spectroscopy, astrophysics

Torrence V Johnson
Planetary surfaces, remote sensing

John J Lambe
Solid-state physics

Robert F. Landel
Properties of polymeric materials

Charles L Lawson
Numerical analysis

Jovan Moacanin
Materials science

Mario J Molina
Atmospheric chemistry

Marcia M Neugebauer
Space plasmas

Donald Rapp
Chemical physics, concurrent processing

Eugene R. Rodemich
Applied mathematics

Zdenek Sekanina
Comet science

Omar H Shemdin
Remote sensing of air-sea interface

Edward J Smith
Space plasmas and fields

Robert H. Stewart
Oceanographic remote sensing

Sandor Trajmar
Molecular chemistry

Hugo D. Wahlquist
Relativity, applied mathematics

William R. Ward
Planetary dynamics, cosmogony

SENIOR RESEARCH ENGINEERS

Victor Galindo
Antenna design and analysis

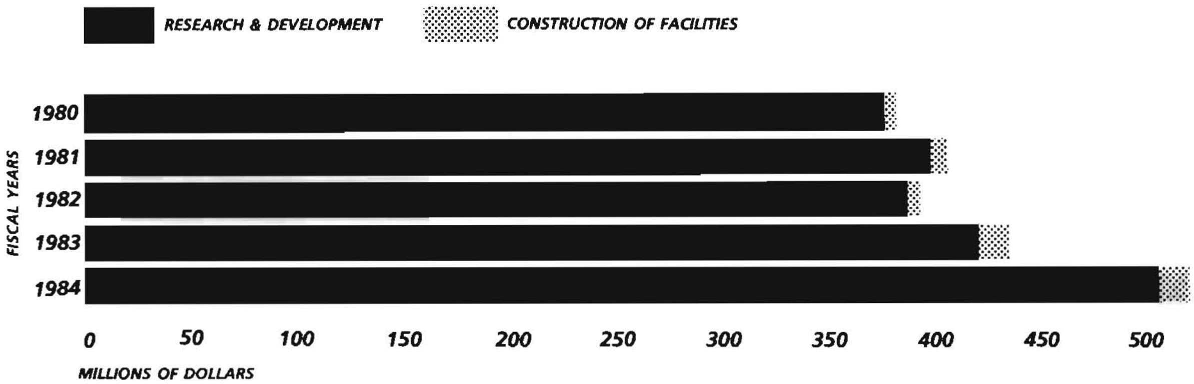
Edward C. Posner
Information and communications

Lawrence L. Rauch
Telecommunications

Marvin K. Simon
Digital communications

Robert C. Tausworthe
Telecommunications, standardized software development

TOTAL COSTS



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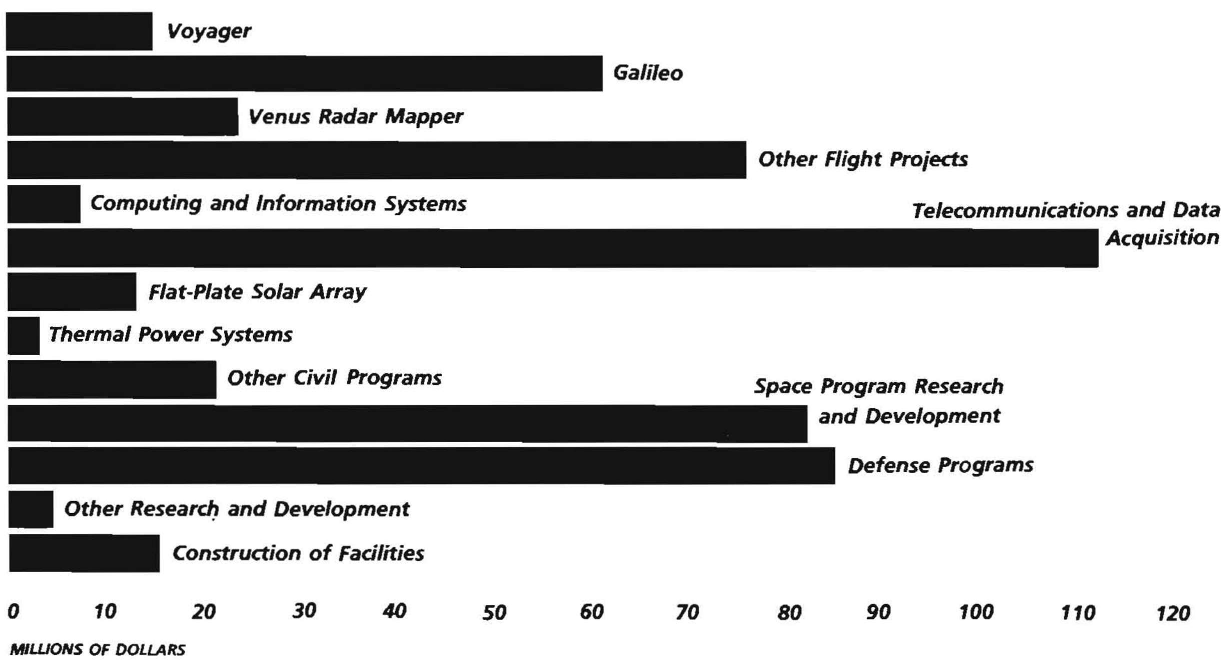
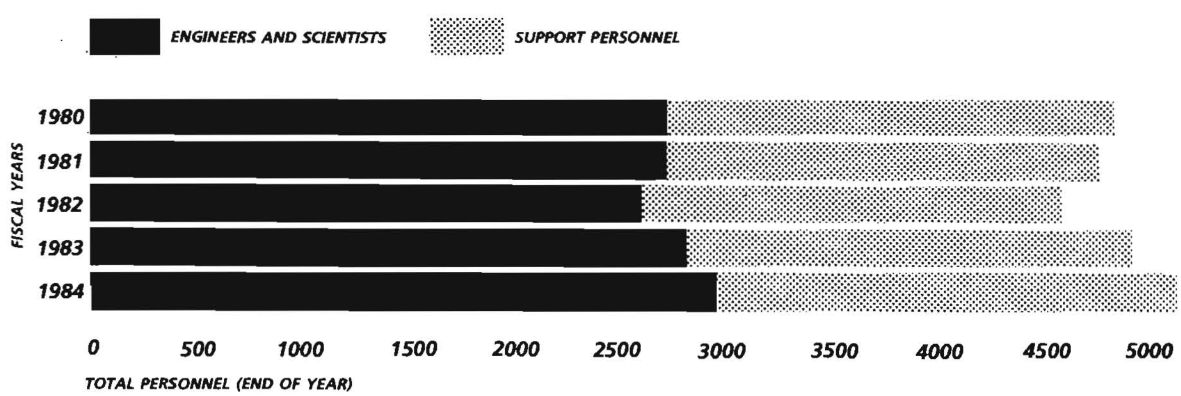


PERSONNEL



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JPL 400-264 8/85